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MEDICAL RESEARCH COUNCIL

E MEDICAL PROBLEMS OF FLYING

UNIVERSITY OF TORONTO
DEPARTMENT OF PSYCHOLOGY

LONDON
BLISHED BY HIS MAJESTY'S STATIONERY OFFICE
1920

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MEDICAL RESEARCH COUNCIL

(Formerly Medical Research Committee, National Health Insurance).

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August, 1920

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Milk and its Hygienic Relations, by Janet E. Lane-Claypon, M.D., D.Sc. (Lond.). Price 9*s.* net. [Longmans, Green & Co.]

The Amoebae living in Man, by Clifford Dobell, F.R.S. Price 7*s.* 6*d.* net. [Bale, Sons & Danielsson, Ltd.]

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THE MEDICAL PROBLEMS OF FLYING

Including Reports Nos. I–VII of the Air Medical Investigation Committee

Special report series, no. 53a

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The following have also served upon the Committee at earlier periods during the war:

Sir Walter M. Fletcher, K.B.E., M.D., F.R.S.
M. Greenwood, M.R.C.P., M.R.C.S. (late Capt. R.A.M.C.).
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INTRODUCTION

During the course of the war, and with successive improvements in artillery, flying was gradually carried to greater and greater heights, so that by the autumn of 1916 'mountain sickness' in its various kinds and degrees gravely increased the difficulties and dangers met by flying officers, and the practical problems of the administration of oxygen at high altitudes by suitable methods had vital military importance. It became apparent also that manifold physiological problems of other kinds were confronting the medical officers in the separate Flying Services who were responsible for the selection of suitable candidates for commissions, for the maintenance of efficiency in the flying men and their restoration after fatigue or damage. During the later months of 1916, the Medical Research Committee had given assistance in France and at home to experimental work undertaken by individual medical officers or civilian physiologists, by supplying special apparatus and in other ways. At the close of that year the Committee formally offered their services in these matters to the President of the Air Board, and supplied some further expert physiological assistance to the experiments and investigations already begun under the Directorate of Military Aeronautics. Early in 1917 an Air Board Research Committee (Medical), which included the Secretary of the Medical Research Committee, was formed to deal with these physiological questions and with other medical problems of aviation, with a view to bringing together more effectively the scientific work being done for the then separate Flying Services, whether in the Navy Medical Department, the Army Medical Service in France, for the Air Board at home, or in University and other laboratories. In particular, the Medical Research Committee gave financial and other assistance to work aimed at finding the most effective means of storing and carrying oxygen in the air and the best method of its convenient administration to flying men. In this country, by permission of the Director-General, A.M.S., the services of Captain J. G. Priestley were provided to follow the lines of earlier work by Dr. J. S. Haldane upon the methods of oxygen administration, and Captain Priestley, in touch with the work being done by Dr. Haldane in the Navy Medical Department, supervised the immediate provision of emergency sets of oxygen apparatus. In France, Professor G. Dreyer (then Major, R.A.M.C.) turned from other work in hand for the Committee, and was afforded facilities for the perfection of an oxygen apparatus devised by himself, which eventually came into general use. In March 1917 the services of Lieut.-Colonel Martin Flack, R.A.F. (then Captain, R.A.M.C.), a member of the scientific staff of the Committee, were placed at the disposal of the Air Board. Lieut.-Colonel Flack dealt in general with the question of oxygen administration and the provision of oxygen apparatus in this country. He began the organization of further studies directed towards finding the most effective tests to be applied to candidates for commissions and detecting the physiological after-results of flying fatigue and strain. For his assistance the services of Dr. Grace Briscoe were placed by the Committee at the disposal of the Air Board for special work at the Central Hospital for Flying Officers established in the building at Hampstead, lent then by the Medical Research Committee to the War Office and later to the Royal Air Force at Hampstead.

In the autumn of 1917, with the prospect of the fusion of the Royal Naval Air Service and the Royal Flying Corps, a new Committee, the Flying Services Medical Advisory Committee, was formed, a sub-committee of which dealt with the questions of medical research. This Committee, in turn, was superseded by the Medical Administrative Committee of the Royal Air Force when that Service was separately established. On both these Committees the Medical Research Committee was directly represented.

In March 1918 the Medical Administrative Committee, in consultation with the Medical Research Committee and with the concurrence of the Air Council, appointed an Air Medical Investigation Committee, (*a*) to

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prepare reports for submission to them with a view to their distribution to those concerned, (*b*) to make suggestions for further co-ordinated medical investigations that might seem desirable, (*c*) to advise them generally in respect of the scientific medical aspects of aeronautics. With the discharge of the Medical Administrative Committee in November 1918 the Medical Research Committee, in consultation with the Director of Medical Services, R.A.F., made arrangements to continue the scientific work of the Air Medical Investigation Committee, and re-appointed it with some modifications in its constitution.

From the date of its inception, the Air Medical Investigation Committee has received and prepared for issue a series of reports upon the scientific work done in this subject. These have been circulated widely through official channels among the medical officers serving with the Flying Services, both at home and abroad, and among officers and others interested in the medical problems of flying in Allied countries.

With the relaxation of censorship regulations after the Armistice, two further reports, respectively by Major Kellaway, M.C., and Major Sydney Scott, were published in the present series (No. 37) by the Medical Research Committee (now the Medical Research Council). It has now been thought desirable that the earlier reports, which contained work of much scientific and medical interest, should be made generally available by publication, and they are here brought together with such additions and emendations as their authors have desired for the inclusion of more recent observations. Many of the tests described in this volume are now in routine use in the Royal Air Force, and the results have already shown that they are valid for the purposes in view.

These various reports are now arranged, not in the order of their former issue during the war, but so as to present in better sequence the problems studied. Additional reports by Dr. Grace Briscoe, the late Dr. L. E. Stamm, and Dr. Rivers and Major Rippon are also now included.

The Medical Research Council are heavily indebted to the Air Medical Investigation Committee for the care they have given to this compilation, and no less to the individual authors who have presented here the results of their work. They would take this occasion of referring with the deepest regret to the untimely deaths of Dr. Corbett and Dr. Stamm, who have contributed to this volume. While connected with the Air Force Medical Service both these officers showed the keenest interest in the study of the medical problems of flying and their loss to the Service and to medical science is very great and widely felt.

The Council have greatly valued the abundant opportunities continuously offered them by the Air Council and by the earlier authorities responsible at various stages for the development of the Flying Services. These opportunities provided a field of work of very great physiological and medical interest. The scientific work actually done during the war not only gave results at the time of immediate military value, but opened up many questions of general medical importance, from the further study of which far-reaching benefits may come. It will not be necessary for the Council to point out that in these present reports they are offering the results of work which, carried out under the trying conditions of war and often in conjunction with heavy duties of a routine kind, has been of necessity in some measure incomplete. It is hoped that knowledge in this subject may be placed upon a more and more trustworthy basis. In the meantime it is believed that the present compilation will give valuable information to all who are interested in the medical problems of flying, and that some of the methods described will be found to give service in medical work wholly unconnected with flying.

Medical Research Council,
15 Buckingham Street,
Strand, London, W.C. 2.

May 10, 1920.

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1.—REPORT ON THE MEDICAL ASPECTS OF HIGH FLYING

BY

J. L. Birley, C.B.E., F.R.C.P., late Lieutenant-Colonel R.A.F. and Medical Officer in Charge, R.A.F., in the Field.

(*First printed March* 23, 1918. *Revised February* 1920.)

A. Preliminary.

It is clearly impossible to draw an absolutely sharp line of distinction between the immediate and remote effects of flying at low as opposed to high altitudes, because many symptoms are common to both types. At the same time, in healthy and fit individuals who fly from 15,000 to 20,000 feet or more, a group of symptoms can be

isolated which may properly be attributed to the physical effects induced by the lowered pressure of oxygen in the air breathed.

It must be borne in mind that the necessity of attention to the technical and other duties of a flight may, in itself, suffice to divert an officer's notice from physical symptoms, unless the latter become imperative, and, further, that one of the most important effects of oxygen starvation is a dulling of the judgement and intellect and an unwarranted sense of well-being and security. In this connexion, the cases of two flight-commanders may be cited who averred they were just as fit at 20,000 feet as on the ground, and scoffed at the idea of using oxygen, while a week later, having both used oxygen for a long flight of more than three hours over 18,000 feet, they were loud in their praises of the benefits it conferred, and made its use compulsory among their pilots and observers.

The most interesting aspect of the whole question, and one of great practical importance, is the remarkable variation met with among individuals who are apparently equally healthy. The use of Flack's bag experiment (see Report 3, this volume, enables one to isolate those very rare cases of men with heart and lungs stethoscopically normal who are so peculiarly sensitive to the effects of even a moderate fall of barometric pressure that they are practically debarred from flying of any description. But beyond these quite exceptional cases, marked differences exist as regards the reaction of the organism to diminished oxygen pressures, and many pilots, especially scout pilots, notice nothing unusual when flying at 18,000 feet.

It should be pointed out that flying at or above 18,000 feet was, in the earlier stages of the war, the exception rather than the rule. The comparative immunity which scout pilots certainly enjoy is largely explained by the fact that they do not maintain great altitudes for very long, and that the actual fighting, with very few exceptions, took place at 15,000 feet or very much lower.

B. Symptoms Noticeable while in the Air.

(*a*) *Dyspnœa.*—This is quite common, and very few pilots breathe through the nose above 12,000 feet. It is often described as 'an inability to fill the lungs with air'. Large numbers of pilots have given me accurate descriptions of periodic (Cheyne-Stokes) breathing at great heights, such as: 'I suddenly begin to gasp for breath, and then do not seem to want any more for a minute or two.'

The slightest exertion brings on dyspnœa, and this is particularly noticeable among observers when fighting, taking photographs, &c. The amount of work involved in fighting is considerably greater than is sometimes supposed.

I have personally experienced Cheyne-Stokes breathing at 20,000 feet, which was at once relieved by breathing oxygen.

The deep breathing persists as long as the height is maintained, but as a rule only causes inconvenience during or after exertion. Pilots being more or less immobilized are much less affected, but there have been cases of pilots arriving back at the aerodrome thoroughly exhausted after having had to use their pressure pump at high altitudes.

(b) Muscular Weakness.—This is complained of chiefly by observers. For example, bending down and drawing the shutter of a camera is often 'hard work'. Several observers have had to break off an engagement even at comparatively low altitudes (e.g. 14,000 feet) owing to exhaustion brought about by standing up in the cockpit and swinging the gun round on its mounting.

I was personally unable to stand up in the observer's seat after being at 21,000 feet for twenty minutes.

(c) Impairment of Judgement and Perception.—This certainly occurs in the great majority of individuals, but frequently passes unnoticed.

The following facts are of interest:

A pilot in a Bristol 'Fighter' met a patrol of 5 E.A. (Enemy Aircraft) at 18,000 feet. He did not realize his danger, but waved his hand to them in spite of the protests of his observer.

Some officers doing long reconnaissances experience difficulty in recognizing the country over which they are flying. As one officer expressed it: 'I could see the ground quite well, but could not puzzle out where I was.'

Observers on high photographic reconnaissances frequently get muddled and fog their plates. They are often unaware of their mistakes, and indignantly attribute the bad results to some fault of the camera. The routine use of oxygen has practically abolished this trouble in one squadron which does a lot of this kind of work.

Pilots who have been up to 20,000 feet have more than once come back with reports of having seen formations of E.A. 4,000 or 5,000 feet above them. It is practically certain that their observations were not correct.

The inefficiency which overcomes pilots and observers at great altitudes is frequently not remarked on by them owing to dulling of perception. This is a most important point, and one that requires systematic investigation both in the laboratory and in the air. At great altitudes there is either a general slackening of morale and loss of offensive spirit, or else a feebleness of judgement which may land a pilot into unnecessary difficulties. In fact, the effects of lack of oxygen on the brain are infinitely more important than the more obvious effects such as hyperpnoea, &c., and constitute for the pilot a subtle and insidious danger of the existence of which it is in many cases impossible to convince him.

(d) Syncope.—It is, in my opinion, a grave mistake to attribute every case of syncope in the air to the lowering of oxygen pressure alone. In very many instances this is only one of the determining factors, and more than 50 per cent. of such cases which have come to my knowledge have occurred below 10,000 feet. Nevertheless there are instances in which the fall of barometric pressure is the main and perhaps the only cause, and, in such, loss of consciousness usually comes on slowly and persists for a relatively long time. In fact, the condition is more like falling to sleep, and I know of a few pilots who state that they have fainted at big heights and cannot remember landing, whereas they have actually been sufficiently awake to fly the machine and land it on their own aerodrome with verbal assistance from the observer.

The following case may be cited :

A squadron-commander was returning from a long bomb raid at 17,000 feet, using oxygen. As he did not begin to descend after crossing our lines his observer roused him and discovered that he had been dozing, his oxygen supply having failed.

Sudden syncope sometimes occurs among observers after making any physical effort, and also occasionally when getting out of the machine.

(*e*) *Overfilling of the Bladder.*—Nearly all officers engaged on long patrols at 17,000 feet or over complain of this, and many of them have to answer the calls of nature while in the air as best they can. This is probably accounted for by the combination of cold and vibration.

(*f*) *Frontal Headache.*—This sometimes comes on while in the air, but more usually after landing.

(*g*) *Vomiting.*—This is very rare indeed.

(*h*) *Haemorrhage from Mucous Membranes.*—This is practically unknown.

C. Symptoms coming on After Landing.

(*a*) *Fatigue.*—This is the most universal and, from a practical point of view, the most important after-result of high flying. All flying is fatiguing owing to the constant stream of stimuli which are pouring in, as, for example, those impinging on the external ear, the internal ear, the eye, the higher centres, muscles, skin, &c. Moreover, many of these are of a character to which the organism is comparatively unaccustomed.

It is only natural that the effects produced when the blood is insufficiently oxygenated should be magnified, and one only has to watch a flight landing after a two hours' patrol without oxygen at 18,000 feet (perhaps the second in the day) to realize the enormous strain which modern flying under active service conditions imposes. Reports of the patrol are laboriously made out at the squadron office, and then there is a general movement to lie down and go to sleep. The gait is often unsteady and laboured, and the general sense of lassitude and fatigue is reflected in the face and general demeanour.

(*b*) *Frontal Headache.*—This comes on shortly after landing, and persists for two hours up to twenty-four or more. At times it is sufficiently severe to render a man incapable of flying.

(*c*) *Cardio-Vascular System.*—Pilots occasionally land with small pulses and low blood pressures, but observations made on aerodromes on active service are both inopportune and misleading.

(*d*) *Respiratory System.*—Shortness of breath and inability to hold the breath for more than twenty to thirty seconds persist for half an hour or so.

D. Acclimatization.

Many flying officers state that they get accustomed to high altitudes. In my opinion this merely means that they get used to the symptoms thereby induced, and there is no evidence that acclimatization in the true sense of the word occurs to a sufficient extent as to render it of any practical utility.

E. Practical Considerations.

Suitable clothing has produced a very noticeable amelioration of the immediate ill effects caused by high altitudes. One squadron has recently been carrying out long bomb raids at 15,000 feet without oxygen, but well equipped as regards clothing, and their pilots have returned to the aerodrome in good condition and with comparatively little fatigue. This is not surprising when the great increase in the respiratory exchange from exposure to cold is borne in mind.

It is also interesting to remember that cold is an extremely important etiological factor in the production of surgical shock, a condition which is closely allied to the condition induced by extreme lack of oxygen in the healthy organism.

The unpleasant effects of flying at great heights are closely dependent on the number of hours flown in a unit of time, and 50 hours high flying in three weeks is productive of greater strain than 100 hours in three months. In other words, the organism must be given time to recover.

Another factor of great practical importance is the length of exposure to heights such as 18,000 feet, and the intervals between flights. Short exposures (scout pilots) are well borne, whereas longer ones are always productive of some of the above-mentioned symptoms. During the winter months, when so many days are impossible for high flying, and the hours are short, the number of breakdowns is reduced to a minimum, and for this happy state of affairs I consider that physical exercise on the ground, which is encouraged and popularized at this time of the year, is also partly responsible.

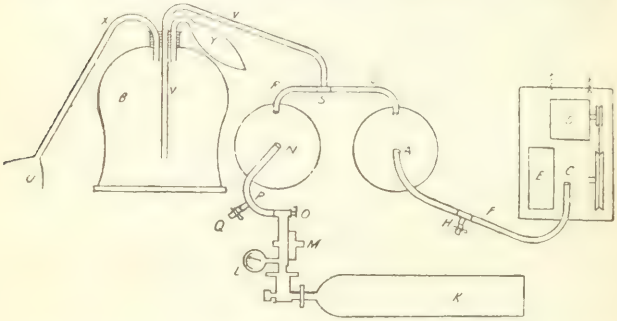
2.—A SIMPLE PROCEDURE FOR TESTING THE EFFECTS OF 'OXYGEN WANT' ON FLYING MEN

BY

Professor G. Dreyer, C.B.E., late Lieutenant-Colonel, R.A.F.

(*First printed March* 23, 1918.)

For the study of the effects of 'oxygen want' on flying men, whether for selection or for the purpose of testing staleness, flying fatigue or other symptoms that may develop as a result of continued flying, particularly at high altitudes, it is important to make use of



a procedure that eliminates other complicating effects of a decreased atmospheric pressure on the organism.

For this purpose the following simple method has been devised. The arrangements are easily seen from the diagram.

A blower (C) (Down's) worked by a small electric motor (D), governed by a resistance (E), allows different quantities of atmospheric air to be passed through an accurate gas-meter (A) by means of a tube (F) of wide bore. From the gas-meter (A) ('air-meter') an exit tube (G) of similar bore is connected with a large container (B) ('breathing chamber') of a capacity of about 30 to 40 litres, preferably about 35 litres.

A T-piece (H) is inserted into the tube (F) connecting the blower with the air-meter. To the free end of the T-piece is fixed a short length of thick-walled india-rubber tubing of a small lumen, to which a screw-clip is attached. By this means a very fine regulation of the quantity of gas passing through the air-meter can be obtained, if a more delicate regulation than can be secured by the electrical resistance, is required. A nitrogen cylinder (K) of a capacity of about 1,000 to 1,500 litres (at 150 atmospheres pressure), and

provided with a manometer (L), a reduction valve (M) and, peripheral to the reduction valve, a stop-cock (O) allowing one to regulate the nitrogen delivery, is connected up by means of wide tubing (P) to a gas-meter (N) ('nitrogen meter') exactly similar to the air-meter. A T-piece (Q), fitted with thick-walled indiarubber tubing of a small lumen, and provided with a screw-clip for fine adjustment of the quantities of nitrogen passing through the nitrogen meter, is inserted into the tubing (P) leading from the nitrogen cylinder to the meter. The exit tube (R) from the nitrogen meter (N) is connected by means of a T-piece (S) to the exit tube (G) leading from the air-meter (A). The inlet tube (V), i.e. the joint exit tube from the two meters, should be passed near to the bottom of the breathing chamber.

The reduction valve made use of should allow quantities of nitrogen of not less than 16 litres per minute to pass through the meter, and the stop-cock should allow regulation of quantities from trace of gas up to a delivery of 16 litres per minute.

Into the breathing chamber is further fixed a wide bore exit tube (X), connected up with a face mask (U).

The mask that I have found preferable to others is the French 'Tizot' mask. It is a tight-fitting mask made of pure india-rubber, fitted with a very light 'knife' valve, arranged in such a manner that it, during inspiration, shuts off all connexion with the external air and allows the air from the breathing chamber to pass freely into the mask, while it, during expiration, shuts off connexion with the breathing chamber and ensures that the expired air shall pass into the external air, thus preventing the expired carbon dioxide from penetrating into the breathing chamber. To prevent the unpleasant and interfering effects of an even slight diminution in pressure caused in the breathing chamber with its rigid walls by each inspiration, an india-rubber bag (Y), for example, the ordinary india-rubber 'bladder' of a football, is fixed into the container.

By the above arrangement it is possible to let pure atmospheric air, or a mixture of atmospheric air and nitrogen, pass into the breathing chamber, and accordingly at will to change the relative proportions between atmospheric air and nitrogen: or, in other words, to change the partial pressure of oxygen at any desired rate, thus obtaining exactly the same effect as if the partial pressure of oxygen were reduced by mounting in the air, gradually arriving at a lower and lower barometric pressure.

The apparatus is used in the following manner:—The electric motor is started, allowing a quantity of about 22 to 27 litres of atmospheric air per minute to pass through the air-meter into the breathing chamber. At this time the T-piece (Q) inserted into the exit tube (P) leading from the nitrogen cylinder should be closed by means of the screw-clip. When the bag is more or less filled, then the person on whom the experiment is going to be carried out puts on the face mask, securing that it fits tightly without leakage. He is now allowed to breathe pure atmospheric air for some minutes. Under these conditions (normal conditions) all control examinations should be carried out—for example, frequency of pulse and respiration, haemoglobin percentage, reaction times, &c.

The tap of the nitrogen cylinder is then opened and by means of the controlling valve increasing amounts of nitrogen gas are allowed to pass through the nitrogen meter. At the same time the amount of atmospheric air passing through the air-meter is gradually diminished in such a manner that the total volume of gas passing into the breathing chamber in each unit of time remains practically the same during the whole experiment. By this procedure it is possible to reduce the partial pressure of oxygen at any rate which is desired (for example, the rate at which it falls when mounting in a fast or medium-fast aeroplane), and to maintain any given pressure for any period that may be required, or suddenly to decrease or increase it, &c.

To secure accurate results it is obvious that the accuracy of the meters should be tested beforehand, and their individual error determined and allowed for in the subsequent calculation. For further control it is also advisable from time to time to make a gas analysis of a sample of the air mixture contained in the breathing chamber, or of the nitrogen used.

It is evident that if equal volumes of air and nitrogen pass through the two meters in the same unit of time, and are properly mixed, the partial pressure of oxygen in the mixture passing into the breathing chamber corresponds to an atmospheric pressure of half-normal or a barometric pressure of 380 mm.

The simplest way to calculate the barometric pressure corresponding to a given oxygen partial pressure in the mixture of air and nitrogen is to observe by means of a stop-watch the times taken by a given volume of air and nitrogen to pass through their respective meters. For instance, the number of seconds it takes for 1, 2, or 2·5 litres respectively. It is preferable to observe the time it takes for 2 or 2·5 litres to pass, because the error of experimentation becomes small or insignificant. If P represents the barometric pressure at the time of the experiment, and T_n the time it takes for a given quantity (for example, 2½ litres) of nitrogen to pass through the meter, and T_a the time it takes for the same quantity, e.g. 2½ litres, of air to pass through the meter, it will be found that if the barometric pressure corresponding to this mixture of atmospheric air and nitrogen is called P_1, then

$$P_1 = P \times \frac{T_n}{T_n + T_a}.$$

The altitude corresponding to a given barometric pressure can then be read off in metres or feet on any of the existing tables.

Example.—If it takes 18·2 seconds for 2·5 litres of nitrogen to pass through the nitrogen-meter, and 10·1 seconds for 2·5 litres of air to pass through the air-meter, then $T_n = 18{\cdot}2$ and $T_a = 10{\cdot}1$; and if the barometric pressure at the time of the experiment is 745 mm., we have an oxygen partial pressure corresponding to an atmospheric pressure of

$$P_1 = 745 \times \frac{18{\cdot}2}{18{\cdot}2 + 10{\cdot}1} = 463.$$

Therefore, the barometric pressure is equal to 463 mm., which corresponds to an altitude of 3,960 metres, or about 13,000 feet.

The advantages of the method are:

(1) That the apparatus is readily put together and can be used in any place, either indoors or in the open.

(2) It does away with all interfering influences of reduced pressure on the internal ear or other organs, and thus allows the pure study of the effects of decreased oxygen partial pressure.

(3) It is possible to investigate not only the changes in reaction time by means of specially adapted instruments, but also to conduct practical experiments, as, for instance, to determine the readiness with which a pilot or observer can orientate himself, aim, fire a gun, &c.

(4) The person conducting the experiment is not himself incapacitated by the effects of "oxygen want", nor does he have to breathe oxygen to obviate these effects, as would be the case if a depression chamber were used.

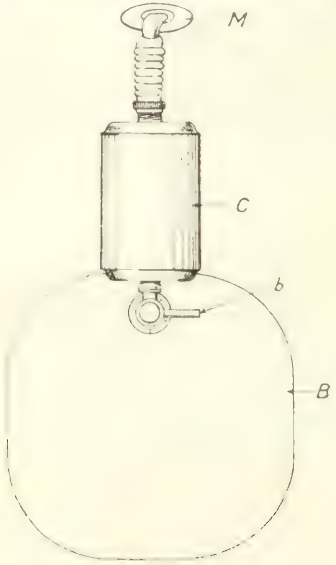
3.—THE BAG METHOD FOR THE INVESTIGATION OF AIR DISABILITIES OF AVIATORS

BY

Lieutenant-Colonel MARTIN FLACK, C.B.E.

(*First circulated July* 1917. *Printed February* 1918. *Revised February* 1920.)

THIS apparatus is of service in affording a quick method of testing a pilot when more accurate means, such as the Dreyer apparatus



A. METHOD.

(previously described) or a rarefaction chamber, are not available. It consists of a rubber mouthpiece (M) fitting over a flat metal tube, which is joined by a flexible rubber tubing to an absorbent cartridge for carbon dioxide (C), which in turn is attached to a bag (B) of about 5 litres capacity. Just below the cartridge is a by-pass tube (b) through which the contents of the bag may be sampled.[1]

[1] The apparatus is manufactured by Messrs Siebe, Gorman & Co. 187 Westminster Bridge Road, S.W.

The subject is given the bag empty, is asked to adjust the mouthpiece comfortably in the mouth, and then to inspire deeply through the nose and blow several times into the bag to fill it. When the bag is just filled to distension a clip is placed on the subject's nose and he is asked to breathe quietly in and out of the bag until he feels he can go on no longer. At this point he expires as deeply as possible into the bag; the flexible tubing is clamped and a sample[1] of the contents taken by means of a vacuum tube from the by-pass, as much air as possible being taken from the cartridge by folding the bag about the main mass of air or closing the entrance hole to the bag with the hand.

This sample, which represents approximately the alveolar air after inspiration and expiration, is now analysed, and the percentage of oxygen in the bag determined. The time of the experiment is taken, also the time at which the breathing deepens appreciably, and any other symptoms such as blueness of lips, circumoral pallor, sweating, &c., are noted. After the experiment a brief account is taken of the subject's experience. From his statements and symptoms observed an opinion can be formed as to whether the subject suffers from 'oxygen want'.

B. Results.

The experiments with normal pilots show that in general the normal pilot will breathe the bag from 3½ to 4 minutes or more, and until the percentage of oxygen reaches 8 per cent. or under. It is interesting to note, however, that some of the pilots just back from hard work overseas do not reach this level. Whether this be due to lack of resolution or to accumulated symptoms of 'oxygen want' it is impossible to say, but the latter view is suggestive.

The chief value of the bag is in the confirmation of symptoms of 'oxygen want' said to be experienced by an aviator. Any one who really suffers from rarefaction of the air quickly develops a hyperpnoea, and usually has to give up breathing inside 2 minutes. When asked to describe the sensations experienced he usually volunteers the remark that they are the same as he gets in the air. Pilots who have fainted in the air have fainted momentarily with the bag experiment. The percentage of oxygen in the air of the bag generally gives an estimate of the height to which the aviator can go without unpleasant sensations. This, however, is not always the case, as a resolute man will push on beyond the stage at which the unpleasant symptoms begin to develop. The calculation is made as follows:

Taking 16 per cent. of oxygen as the content of the alveolar air on the full vital capacity at 760 mm. Hg (average of many estimations), then by simple proportion the number of millimetres of Hg corresponding to the percentage of oxygen can be calculated. Thus, supposing the bag content is 11·5 per cent., then

$$\frac{760 \times 11{\cdot}5}{16} = 546 \text{ mm. Hg.} = 9{,}000 \text{ ft. (approx.).}$$

[1] The carbon dioxide in this sample must not exceed 0·2 per cent., otherwise the result of the experiment is unreliable. The presence of unabsorbed carbon dioxide increases the power of the subject to continue the experiment, hence the calculated height will become too high.

TABLE GIVING RELATIONSHIP BETWEEN OXYGEN CONTENT OF BAG, BAROMETRIC PRESSURE AND ALTITUDE.

Percentage of Oxygen in Bag.	*Barometric Pressure* (15° C.) *in mm. Hg.*	*Approximate Altitude in feet.*
15	713	2,000
14	665	3,800
13	617	5,700
12	570	7,900
11	522	10,500
10	475	13,000
9	427	15,800
8	380	19,000
7	332	22,600
6	285	27,000
5	237	over 31,000

This has been confirmed several times by the use of the experimental rarefaction chamber. Lt. C., who breathed the bag until the oxygen content was = 17,500, staggered about and felt ill in the chamber in an atmosphere corresponding to 18,000 feet. 2/Lt. S, who with the bag felt symptoms, with a percentage corresponding to 9,000 feet, felt the same symptoms in the air badly at 9,500; generally slightly about 7,000 feet; and in the experimental chamber at 10,000 feet.

In the following table is given the calculated altitude, by the bag method, to which the subject can fly before symptoms develop and the actual altitude at which symptoms have developed.[1]

No. of subject.	*Calculation height.*	*Height at which symptoms develop.*
1	Just over 4,000	4,000.
2	6,000	4,000.
3	8,800	Max. 10,000; fainted twice above 8,000.
4	4,000	3–4,000.
5	Just above 8,000	Max. 11,000; uncomfortable about 5,000.
6	7,000	4,000 (after long flight).
7	9,000	Max. 9,500; queer above 7,000. Confirmed in chamber at 10,000.
8	4,400	Pains in head, 3–4,000.
9	Just below 6,000	About 6,000.
10	Nearly 17,000	Headache after long time, 7–10,000.
11	6,000	Begins to feel suffocated at 7,000. Fainted since crash at 8,000 and 10,000.
12	16,000	Difficulty at 5,000, only four hours flying
14	17,500	Vomiting twice after crash. Confirmed in chamber as 18,000.
16	3,000	Fainted three times below 5,000.
17	4,000	Above 3,000.
18	4,000	Dizzy and sick above 4,000.
23	4,500	Giddy and faint about 5,000.
25	5,500	Dizzy and headache, 5–6,000.
29	5,000	Pressure in head; blurring of vision; 5–6,000.
32	4,500	Giddy, 5,000.
34	10,000	Constant headache about 8,000.

It will be seen that in many cases the agreement is striking, but, as already mentioned in some cases, allowance has to be made for the fact that the subject pushes beyond the beginning of the unpleasant stage, e.g. Nos. 10 and 12.

[1] Many further cases have been examined since this table was compiled

The results are, however, sufficiently near, since the chief object of the bag experiment is to confirm the pilot's statement, and future flying will be confined to several thousand feet below that at which symptoms develop.

The bag is also of service in the diagnosis of the neurasthenic or the man suffering from lack of resolution. Such a person gives up the bag without exhibiting any marked symptoms, and does not generally describe any sensations to be attributed to want of oxygen. The neurasthenic usually ventures some such remark as 'beastly' or 'horrid'. One such could only breathe the bag for 38 seconds. On the other hand, some subjects unsuspectingly attain a diminution of oxygen far in excess of the utmost height to which they say they can ascend, as, for example, a man who always suffered anxiety at 5,000 feet reached a percentage of oxygen corresponding to 18,000 feet without much discomfort.

C. Conclusions.

(1) The bag method described is of service in confirming statements made by aviators as to disabilities presumably due to lack of oxygen.

(2) After analysis of the oxygen content of the bag, by simple calculation an estimate in most cases can be arrived at of the approximate height at which such symptoms should develop.

4.—A STUDY OF THE REACTION OF PILOTS AND OBSERVERS TO DIMINISHED OXYGEN-PRESSURE

BY

The late C. D. H. Corbett, M.D., M.R.C.P., late Lt.-Col., R.A.F., and H. C. Bazett, O.B.E., M.C., M.B., F.R.C.S., late Capt., R.A.F.

(*Printed November* 14, 1918. *Revised, with appendix, February* 1920.)

The investigations with which this paper deals have been carried out at Nos. 14 and 24 General Hospitals, B.E.F., as part of an examination of a large number of flying officers. It frequently happens that a flying officer complains of a group of symptoms of such a character as to suggest that they are caused wholly or partly by the diminution of oxygen-pressure which exists at high altitudes. Although in some cases the symptoms complained of in the air are capable of confirmation by evidence, medical and otherwise, obtained after landing, in other cases we have to depend solely on the individual statement of what happened many thousands of feet above the ground. Our observations have a practical value, a point on which we would like to insist. Their main object is in fact to determine whether or not the symptoms of which the patient complains are the result of oxygen-want. If this is found to be the case, it has further to be determined whether the individual is fit to continue the particular type of flying on which he has been employed, and in certain cases whether he is fit to continue flying of any description. In this connexion it must be pointed out that on active service there is no 'graduated flying': and the pilot who is physically incapable of doing his full share of work merely increases the work of his brother officers.

In the course of our work we have had opportunities for studying the changes induced in the cardio-vascular and respiratory systems by exposure to air deficient in oxygen. We propose to describe these changes in some detail, but it is not our intention to enter into an academic discussion either of their physiological significance or causation. Our chief concern is to describe accurately such facts as we have observed and to emphasize those which appear to us of practical importance.

We should like to take this opportunity of drawing attention not only to the remarkable variation among individuals in their capacity to withstand lack of oxygen, but also to the varying character of the disturbances evoked by oxygen-want. Of these disturbances, dulling of perception is certainly the most important and probably the most common, while it is interesting to note that only

a small number of the patients examined gave a history of fainting in the air. It would also appear probable that the bodily changes by which the organism adapts itself to oxygen-deficiency are not of a standard pattern but are capable of a certain amount of individual variety.

Before proceeding to describe the methods employed and the results observed we propose to say a few words on the broad question of flying at high altitudes. In the first place, one cannot but be struck by the complete immunity from any discomfort which some individuals enjoy during arduous and protracted terms of high flying, and by the comparative immunity enjoyed by the vast majority of scout pilots. The conclusion is forced upon us that the normal healthy individual, especially if by virtue of his previous mode of life he has learnt to make full use of his lungs, can endure the strain of flying up to 18,000 feet for a considerable time without loss of efficiency. The more immediate explanation of this must be sought in the comparative immobility of the flying officer and his machine, and in the stimulating effect of the cold air on the face, the trunk and limbs being protected from cooling by suitable clothing.[1] The more remote explanation of this immunity is, however, to be found in the physical fitness of the individual, and in view of this we would strongly urge that the care of the body should form an essential feature of the training of cadets. We have seen numerous pilots who appear hardly to have heard of physical fitness and have never learnt to take any sort of pride in their bodily health.

Secondly, we wish to point out that out of a thousand flying officers who have passed through our hands no case has come to our notice of any organic changes in the respiratory or circulatory systems which could possibly be attributed to the effects of flying. It is possible, however, that long-lasting alterations in the mechanism which regulate respiration may be produced by a prolonged spell of flying at great altitude.

Thirdly, we do not suggest that the methods employed are necessary for routine use in the examination of candidates for the air service. The respiratory tests (1) described by Lieutenant-Colonel Flack (Report No. 7) are of great assistance to medical examiners in determining the physical fitness of an individual, and therefore his physical fitness for flying. Although it is true that an individual who is well below normal on the manometer test is useless for high altitude flying, we have found some who, while quite good at this test, are also incapable of enduring want of oxygen. Further, it is impossible to assess the degree of respiratory fatigue in tired pilots by this means unless some record has been kept of their normal performance.

Fourthly, it is evident that many officers proceed overseas with an unjustifiable dread of the effects of high altitudes, and it is not surprising that on their first flight to 15,000 feet or over the hyperpnoea of which they become conscious should alarm them and lead them to imagine that they are unfitted for such work. It would therefore appear of great advantage if pilots, and to an even greater

[1] Several officers when being tested by Dreyer's method have expressed a desire to 'put their heads over the side'

extent observers, who will be expected to fly at great altitudes overseas, could be sent up at least once in England to 15,000 feet, and kept at that altitude for at least 30 minutes, if only to be reassured and to 'see what it is like up there'.

In the earlier part of our work considerable use was made of Flack's bag, (2) and this method proved of great value if the changes in pulse-rate and respiration were observed. But although this test picks out many men who are incapable of flying at high altitudes, the results are often not conclusive, since an individual may be able to withstand these adverse conditions for a few minutes, while he is quite incapable of enduring oxygen-want for any length of time. The results obtained by this method will be summarized later in this report.

The exhaustion-chamber method has not been employed, partly on account of the expense and labour involved, but mainly owing to the introduction of Dreyer's method (3), which frees the examiner from the heavy handicap of being exposed himself to a rarefied atmosphere.

As compared with the bag test the Dreyer method, while certainly somewhat elaborate, reproduces much more exactly the conditions to which airmen are exposed. We have come to use it as a routine, and only use the bag when pressed for time. A few cases have been examined by both methods for the sake of comparison.

Up to the present time fifty cases have been examined by the Dreyer method, and of these a very large number were officers who had been overseas a very short time and were considered by their Squadron Commanders unsuited for high altitude work. In the majority of these cases the opinion of the Squadron Commander has been confirmed, but happily not in all.

A. Testing with Flack's Bag.

The method has already been fully described elsewhere. Some seventy cases have been tested in this way, some of them more than once, and one of us (D. C.) has experimented several times on himself. In most of the cases the pulse-rate throughout was taken by hand, and in a few instances the changes in respiration were recorded on a revolving drum, a pear-shaped bag, 6 inches long, with an internal spring, being strapped just below the xiphisternum and recording to a tambour. With the kind assistance of Lieutenant-Colonel Dreyer a careful investigation was conducted in some cases as to whether blood-concentration occurred.

It is necessary to emphasize one precaution that must be taken to ensure uniformity of results. If the caustic soda cartridge is not absorbing properly, varying proportions of CO_2 will remain which will entirely upset one's conclusions.

A proportion of CO_2 exceeding 0·3 per cent. assists the individual to breathe more deeply, so that he reaches a 'greater altitude' on the apparatus, a lower percentage of oxygen being found on gas analysis. If the proportion rises above this the results are not comparable and the experiment is valueless as a test. There is no means of telling beforehand whether the cartridge is working properly:

if found to be defective the experiment was always repeated later with a new one.

The results obtained may be summarized as follows, the respiratory response being considered separately.

In addition, a table (Table A) is included, giving some instances of each class of case, together with some charts of the changes observed (Charts 1 and 2).

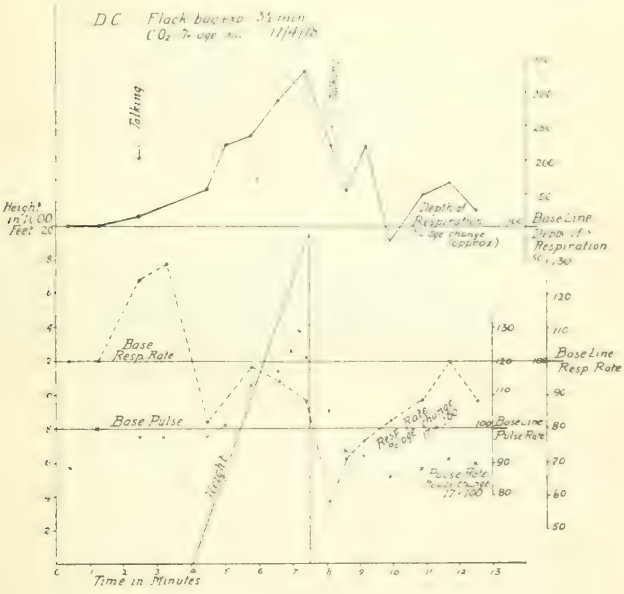


CHART 1

A. *The Normal Response.* A person of good physique and capable of withstanding altitude will persist for from 3 to 3½ minutes and an analysis of the air remaining usually gives 6 to 7 per cent. O_2, corresponding to 20,000 to 25,000 feet. That is apparently the average rate of consumption of O_2 in good types.

The pulse-rate should show a steady rise from the start. At the end it should reach about 100 per minute, and should not exceed 120. When the bag is removed it should at once fall and resume its normal rate in about 5 minutes.

B. *Abnormal Responses.* 1. Failure may occur as the result of cardio-vascular collapse. This type may faint and suffer subsequently from dizziness and headache. The changes in pulse-rate vary according to the type of case.

TABLE A. RESULTS WITH FLACK'S BAG

Type.	*Time.*	*Altitude.*	*% CO_2 in Sample.*	*Pulse Rate.*	*Remarks.*
Normal. (1) 2/Lt. C. J. F.	3½ min	25,000 ft.	Nil.	*At start* 68 1 min. 80 2 min. 96 3 min. 112 3½ min. 120	Scout pilot. Due for home establishment. A little stale.
(2) Capt. G. C. M.	3¼ min.	25,000 ft.	0·47 %	*At start* 64 1 min. 88 2 min. 88 3 min. 104 3¼ min. 108	Scout pilot. Due for home establishment. A little stale.
Abnormal. I A (1) Lt. C. E. T.	2¼ min.	16,800 ft.	Nil.	*At start* 92 1 min. 120 2 min. 128 2¼ min. fainting.	Headache and dyspnœa above 10,000 ft. Observer on prob. 40 hours in France. Boarded permanently unfit flying.
(2) 2/Lt. J. F.	2¼ min.	14,000 ft.	Nil.	*At start* 100 1 min. 128 2 min. 144 2¼ min. fainting.	Dizziness at 8,000 ft. and over. 35 hours in France. Boarded permanently unfit flying.
B (1) 2/Lt. W. C. T.	2½ min.	15,000 ft.	0·1 %	*At start* 80 1 min. 100 2 min. 112 2½ min. 112 fainting.	Dyspnœa at 6,000 ft. and over. No flying in France. Giddiness on exertion. C.V.D. Boarded permanently unfit flying.
2 Lt. R. L. R.	2½ min.	15,000 ft.	0·1 %	*At start* 56 1 min. 72 2 min. 80 2½ min. 96 2½ min. 88 fainting.	Loss of sense of equilibrium at low altitudes. Boarded permanently unfit flying.

C (1) Lt. R. H. H.	1¼ min.	10,000 ft.	0·1 %	*At start* 114 1 min. 100 1½ min. 100 1¾ min. fainting. 4 min. later P. = 104.	180 hours on scouts. Very exhausted D.A.H. type of pulse.
(2) Capt. G. C. W.	2¾ min.	30,000 ft.	0·6 %	*At start* 80 ¼ min. 100 1¼ min. 92 1½ min. 80 2¼ min. 68 2½ min 60 fainting. 15 sec. later 96 5 min. 92 6 min. 80	Fainted at 4,000 ft. when on patrol Rapid oxygen consumption probably due to CO excess.
Abnormal. H. (1)	2½ min.	22,600 ft.	Nil.	*At start* 80 1¾ min. 100 2 min. 156 syncope.	Giddiness in air 10 hours in France.
(2)	2¼ min.	20,000 ft.	Nil.	No record. Gave up. Felt heart beating.	Giddiness in air. 80 hours in France

(*a*) In cases who are physically incapable of standing altitude and may have done little flying the rate rises rapidly and may become uncountable. Syncope may occur early.

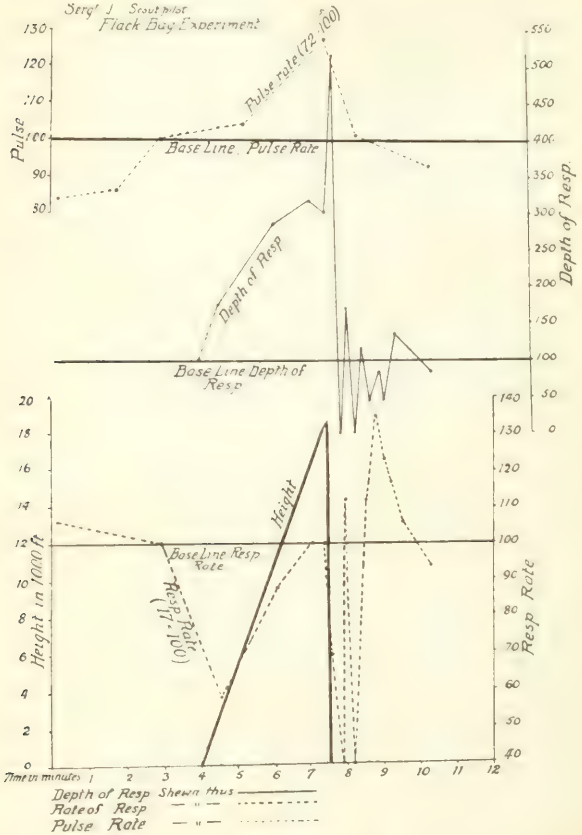


Chart 2

(*b*) In others syncope may also occur at a comparatively low altitude, but without an excessive rise of pulse-rate.

(*c*) In cases of oxygen-want, due to exhaustion, who have done a great deal of flying with perhaps a history of fainting in the air, the pulse-rate may rise during the first half-minute and then remain

stationary or gradually fall below its rate at the start. As soon as the bag is removed the rate rises.

2. In another type the oxygen consumption is abnormally rapid, leading to failure in under 3 minutes at an 'altitude' reached by a good type in 3 to 3½ minutes.

(a) The Respiratory Response.

Only in a few cases was the respiration recorded. In every instance the depth at first increased, and the rate remained slightly raised or stationary, although in good types it was diminished. In these latter the depth was maintained, while a response was considered to be bad when the respiration became more shallow towards the end and when periodic breathing occurred when the bag was removed.

(b) Blood Concentration.

This was observed in some cases, but it was a very transitory phenomenon. It was found within 2 minutes of the removal of the bag, and had disappeared 4 or 5 minutes later. The maximum concentration seen was under 5 per cent. No conclusions could be drawn from the results obtained as to its value from the point of view of diagnosis.

Appended are some details of bag experiments where the respiration was simultaneously recorded.

A. Normal response.

D. C. has never flown at high altitudes.

Height reached 20,000 feet in 3½ minutes.

Pulse rose from 77 to 100 per minute at 3¼ minutes, falling to 68 after the bag was removed.

Respiration.

(*a*) Rate fell steadily throughout the experiment.

(*b*) Depth steadily rose.

There was a compensatory rise of both rate and depth after the experiment, with very little tendency to periodicity. 20,000 feet is the usual height reached by D. C. in 3½ minutes (Chart 1).

B. Abnormal.

1. *A. D. S.* History of oxygen-want at 18,000 feet, evidence of cardio-vascular debility, pulse easily raised by exercise. The case is interesting in that it shows the effect of the presence of 1 per cent. CO_2 in the bag in greatly increasing the 'altitude' reached in a given time. The general condition of the patient was about the same at the end of the two experiments.

(*a*) With CO_2 1 per cent.

Height reached 26,000 feet in 3½ minutes.

Pulse rose from 89 to 133 at 3 minutes.

Respiration an increase both in depth and rate.

(*b*) With CO_2 nil.

Height 14,000 feet in 3 minutes.

Pulse rose from 96 to 115 at 2½ minutes, and then fell a little, and was probably falling towards the end of the experiment.

Respiration not recorded.

Of the two experiments the second alone gave any accurate

information as to the capacity of the patient to withstand oxygen-want, which was really rather poor.

2. *Sgt. J.* History of breathlessness at 12,000 feet, and occasional attacks of breathlessness night and morning.

Height 18,400 feet in 3½ minutes.

Pulse rose from 80 to 97 only, a subnormal response.

Respiration.

(*a*) Rate fell at first, rising to normal.

(*b*) Depth was very rapidly increased with marked hyperpnoea just before the bag was removed.

At the end of the experiment there was very definite periodic breathing, the rate showing 100 per cent. variations, while the depth showed only slight corresponding changes.

This patient was evidently of the type liable to periodic breathing at altitudes, which we have been able to show in our later work is often associated with a subnormal cardio-vascular response (Chart 2).

3. *Lt. P. E. H.* Fainted at 14,000 feet, recovered at 4,000 feet.

This case comes under the heading 1 (*a*) above of abnormal responses. He was subsequently tested on the Dreyer apparatus, and a chart of this experiment (Chart No. 11) is given later.

Height 17,000 feet in 2 minutes.

Pulse rose from 92 to 156, and was still 104 2½ minutes after the bag was removed.

Respiration.

(*a*) Rate rose slightly.

(*b*) Depth was very considerably increased.

In this instance syncope apparently occurred from cardio-vascular failure only, the respiratory response being well marked, though somewhat excessive. On the other hand, on referring to the Chart No. 11, illustrating the Dreyer experiment, it will be seen there that the failure was essentially respiratory in origin.

Tests by Breathing through a Long Tube.

A certain number of experiments (15) have been made in which the patient has breathed through a long tube, so that his supply of fresh air has been in this way much diminished, while the carbon dioxide has been absorbed by caustic soda. The patient wears a nose-clip, and breathes through a short flexible tube connected with a tin containing coke, through which runs a constant stream of 20 per cent. caustic soda. The lower end of the tin has an opening connected with large-bore rubber tubing, the length of which can be altered so that the supply of fresh air can be increased or decreased at will. The tubing used was of ¾ in. diameter, and lengths of tubing varying from 42 cm. to 185 cm. were employed. The dead space was in this way increased by a volume of 1,160 c.c. below the caustic soda and 70 c.c. above it, a total of 1,230 c.c. with the greatest length of tubing and with a length of 142 cm. (the length most commonly employed) 1,120 c.c. From the short flexible tube above the caustic soda receptacle a piece of pressure tubing is led out, allowing samples of alveolar air to be taken at any time during the experiment.

This method was tried by one of us (H. C. B.) in an attempt to find

a portable apparatus for testing for altitude, but it has not proved satisfactory for this purpose. The apparatus is practically the same as that employed by Douglas and Haldane in their investigation of Cheyne-Stokes (4) breathing. In any patient with a given length of tube a very constant 'altitude' will be maintained and the blood-pressure and pulse-rate changes correspond very closely with those seen under the conditions of a Dreyer test, but it seems to be impossible to decide how long a tube any patient will require to maintain him at a reasonable 'height', and the degree of oxygen-want to which he has been subjected can only be decided by alveolar air analysis. While in one subject an increase of 40 cm. in the length of the tube would make a difference of 5,000 feet in altitude, and the patient would reach 23,000 feet with a length of 142 cm., and another would only reach 12,000 feet with a length of 185 cm. No relationship could be found between the 'altitude' reached and either the vital capacity or normal tidal air of the individual, but the results seemed to depend on whether he responded by breathing deeply. The 'altitude' reached has been calculated from the percentage of oxygen found in the alveolar air, 14 per cent. being taken as the normal. Owing to the difficulty of deciding what length of tube should be employed in any case, the method has been entirely given up as a practical test. For though the results obtained, if the respiratory and cardio-vascular changes are recorded, are of greater value than those obtained by the Flack's bag, this method is rather more troublesome to use, and the test must be continued for at least 30 instead of 3 or 4 minutes. That the effect produced corresponds closely with that obtained by Dreyer's method has been demonstrated by subjecting four people to both tests. A remarkable similarity was noticeable in the reactions observed, the only difference being a slightly greater rise of systolic blood-pressure in the tube experiments. This was probably due to the amount of work the subject had to do in order to obtain his air. Charts 6, 10, and 12 show the results obtained when the same patients were tested both by this and by Dreyer's method.

The tube method is therefore only described here, owing to the light it throws on the changes in the alveolar air, resulting from a degree of oxygen-want similar to that used in a Dreyer experiment. It was found that the CO_2 percentage remained constant in most cases at 'heights' below 15,000 feet. Where the oxygen percentage in the alveolar air had been reduced to about 50 per cent. of normal (i.e. 18,000 feet) the CO_2 percentage was reduced slightly, an average of 6·1 per cent. being found at the commencement and 5·64 per cent. at the end of the experiment (about 30 minutes).

In marked contrast is one case of the excessive respiratory reaction type (see Chart 10 and Table C, 36). In this patient the respirations became excessively deep and rapid, so that the altitude reached was less than 9,000 feet and was quickly lowered still farther, while the CO_2 percentage starting at 6·1 per cent. was reduced to 4·5 per cent. Although no deductions can be drawn from a single experiment this result is suggestive, considering the extraordinary excessive respiratory response, and especially as no such change in the alveolar air was ever observed in the more normal subjects tested by this method.

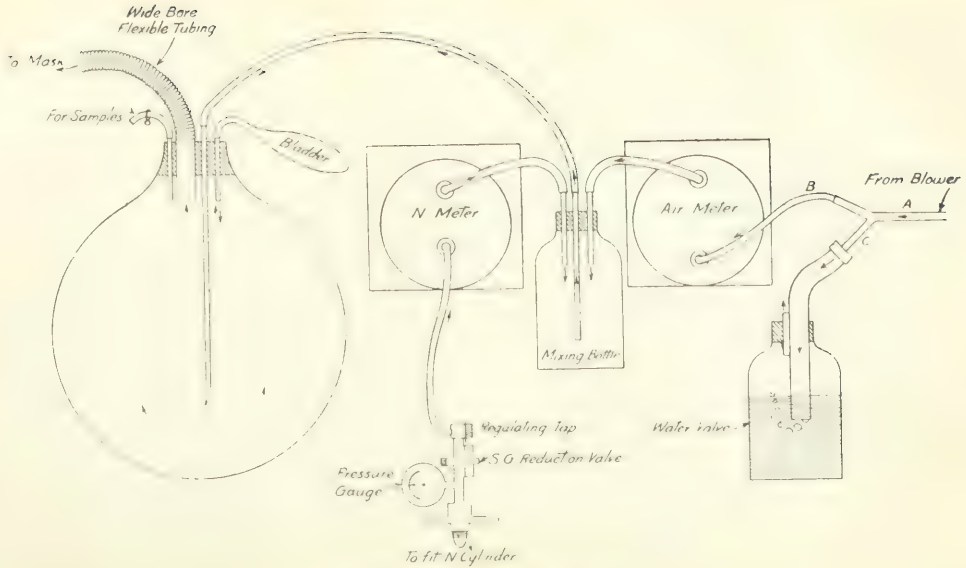


FIGURE I. Diagram of Dreyer Apparatus.

B. Dreyer's Method.

(*a*) *Apparatus.*

It was found necessary to make certain modifications in the apparatus as originally figured by Colonel Dreyer. In the first place a large mixing bottle was used instead of the T-piece, in order that the air and nitrogen might be well mixed before passing on to the large reservoir. In the place of a large bell-jar we used a glass sulphuric acid carboy of 40 litres capacity, as this can be easily obtained.

There was at first considerable trouble with the air-supply, the current available for the motor being very variable, so that one could not ensure a constant mixture.

The governing device illustrated was found to be very useful in getting over this difficulty, and consists in a simple water safety-valve (Fig. I).

(*b*) *Description of Water-Valve.*

The air from the blower is by a tube 'A' to a T-tube of quite $\frac{1}{2}$ in. internal diameter. From one aperture of this a tube 'B' goes to the inlet of the air-meter, and from the other a tube 'C' is connected with a tube of $\frac{3}{4}$ in. bore, dipping into a large wide-mouthed bottle three-parts filled with water. Some device must be used to fix the tube at any desired depth without restricting the outflow of air from the neck of the bottle. When the motor is started its rate is so adjusted, and the tube is set at such a depth in the water, that the air just bubbles out from its distal end, and the air meter shows 2·5 litres in 7·5 seconds (this being the volume of air delivered to the patient before the nitrogen is turned on). If the motor happens to slow down slightly the resistance of the water will prevent any escape of air from the tube, or again, if its speed is increased somewhat the excess of air delivered will bubble away instead of going through the meter. When it is desired to reduce the amount of air delivered the tube is simply pulled up, allowing more air to escape while the speed of the motor is kept constant. In this way a very steady and accurate volume of air can be delivered.

For the delivery tube to the mask we used Douglas flexible tubing of 1 in. internal diameter, as a narrow tube should be avoided.

A small piece of pressure tubing was fitted into the mouth of the large reservoir in order that samples of the mixed gases might be taken for analysis. As a general rule this is not necessary and was only done occasionally as a control.

(*c*) *Method of Working.*

The motor is started and adjusted with the water-valve to deliver 20 litres of air per minute to the patient. It has been found that this supply has been ample in all cases tested to keep the patient comfortable even in case of hyperpnoea, and throughout the experiment the total volume of mixed gases delivered was kept constant at 20 litres. Before deciding to what altitude the patient should be taken, attention is paid to the history of the case. Three stages have been generally used, 12,000 feet, 15,000 feet, and 18,000

19,000 feet. For these the meter times for one complete revolution (2·5 litres) are as follows :

		Air.	*Nitrogen.*
Stage 1.	12,000 feet	10·5 secs.	19·5 secs.
Stage 2.	15,000 feet	13 secs.	17 secs.
Stage 3.	18–19,000 feet	15 secs.	15 secs.

It might be as well here to requote Col. Dreyer's formulae for calculating the equivalent barometric pressure of the mixed gases :

$$P_1 = P \times \frac{Tn}{Tn - Ta}$$

Where P_1 = barometric pressure looked for.
P = barometric pressure at time of expt.
Tn = time for $2\frac{1}{2}$ litres of N to pass in seconds.
Ta = time for $2\frac{1}{2}$ litres of air to pass in seconds.

It has been found that pilots are better able to stand altitude in air where the barometer is much above normal, the converse being also true. Similarly, when the barometer is high patients are able to stand a lower percentage of oxygen when tested by this method.

The average barometric pressure at different altitudes can be seen according to the following table :

Feet	Mm. Hg.
8,000	570
10,000	530
12,000	494
14,000	460
16,000	428
18,000	398
20,000	370

The patient is usually taken up to 15,000 feet straight away, and it has been calculated that he will reach this height in between 5 to 10 minutes owing to the dead space of the apparatus. The observation of the patient is dealt with below. Care should be taken as far as possible to cut down the air and turn on the nitrogen without attracting his attention. If the reaction is unsatisfactory or if there is anything in his history to warrant it he is kept at this height, otherwise after a short time he is taken to the next stage, where he stays until the end of the experiment, or he may be brought down again to the lower level.

Early evidence of syncope will be afforded by a considerable fall of blood-pressure, preceded by a gradual rise of diastolic pressure. As soon as this or any other indication occurs for stopping the experiment the nitrogen is turned off and the supply of air increased to its original volume, the mask being kept on. In this way the after-reaction can be observed under the conditions of the experiment. As soon as the air is turned on, as described, the patient is almost immediately aware of his improved conditions, although, as before, the change from one level to another will take from 5 to 10 minutes.

In a few cases it was necessary to cut short the experiment by removing the mask before the nitrogen was turned off.

The sensations experienced by the patient correspond very closely with those produced in actual flying conditions, and many pilots have been able to estimate correctly the artificial altitude to which they were being exposed. A statement by one of them, an experienced flight commander, is appended :

' In my opinion the Dreyer apparatus for testing pilots for high flying is extraordinarily good.

' The sensations experienced at 20,000 feet in the air are exactly the same as those produced when tested by this apparatus on the ground at normal atmospheric pressure.

' During the test, when the amount of oxygen breathed was greatly reduced, I felt very cold in the feet and hands, symptoms which I had previously attributed to the intense cold experienced at great heights.

' The feeling in my head was exactly the same except that I did not feel as if my head were bursting, as is the case when one is flying at a great height for a long time.

' The mask does not restrict the breathing in any way.'

(*d*) *Blood-Volume Changes.*

Time has not allowed any thorough investigation of this subject, and the number of observations made has not been very great. Up to the present time no samples of blood have been taken from veins, but only from the capillary circulation, and it has been assumed that the blood-volume has varied inversely as the proportion of haemoglobin in the peripheral blood. Four drops of blood are taken from an ear or finger without squeezing into a paraffined watch-glass, and from this 0·05 c.c. is sucked up into a graduated pipette and added to 9·95 c.c. of normal saline in a test-tube, thus making a 1-in-200 suspension. The test-tube is gently rotated to allow mixing, and then no clotting should take place, if the saline has been made with clean distilled water. A number of samples are taken in this way, before, during, and after a Dreyer test. These blood-suspensions are allowed to settle and will keep a few hours at room temperature, but as soon as possible after the experiment, when all the blood-samples have been collected, the test-tubes are again gently shaken to mix and a few grains of saponin are added to each to cause haemolysis. The resulting haemoglobin solutions are compared with each other in the Duboscq colorimeter, artificial light in a dark room being used for this purpose. In this way even small changes can be detected and carefully measured. The original samples are taken before the patient is submitted to oxygen-want ; these should agree with one another and are reckoned as 100 per cent., while the others are all compared with them, the percentage change being estimated. Care has to be taken to obtain the blood under exactly similar conditions, without squeezing and in the same amount, and the time taken between bleeding and sucking up the blood in the pipette should be kept as constant as possible, as settling of the corpuscles quickly occurs and may cause errors. For this method, which has proved extremely accurate in use, we are again indebted to Col. Dreyer.

(*e*) *Cyanosis.*

Cyanosis develops in all patients at or about 'heights' of 18,000 feet, but it comes on slowly and is not seen as soon as that height is reached. No definite differences have been noticed in this respect between various individuals.

(*f*) *Physical Work.*

Physical work has been used while the patients were subjected to oxygen-want to increase the severity of the test. As far as possible this work has been made similar to that which might have to be done in the air. The most useful test has been the blowing up with a pressure pump of an imitation petrol tank, the patient being required to raise the pressure to four atmospheres in spite of a leak which is always tending to lower it. The effect of this on his respiration and pulse-rate has been noted. On other occasions the patient has been made to stand up.

(*g*) *Mental Work.*

The ability of the patient to perform mental work has been tested chiefly by arithmetic. A simple division sum has been given him when he has been receiving pure air wearing the mask, and this sum is repeated when he is at an 'altitude'. The time taken over the sum is recorded in each case, but is invariably longer when the patient is exposed to oxygen-want, in spite of the fact that he is repeating the sum for the second time. The patient is peculiarly liable to mental symptoms at altitudes, gross errors are made in the sum, and he is often quite incapable of finishing it.

(*h*) *Subjective Symptoms.*

The patient will usually complain of a number of symptoms such as headache, sleepiness, shortness of breath, praecordial pain, abdominal pain, dizziness or faintness. Only one case has shown any inclination to vomit. The symptoms are noted. If carried sufficiently far the sensations resemble very closely those of a man going under an anaesthetic, but it is quite unnecessary to carry the experiment to this length. On returning to full air the headache, if it has been present, usually continues for some hours or may even last a day or two. Of all symptoms headache and sleepiness are the most common.

C. Observation of the Patient.

Care must be taken to exclude excitement in the patient. The mask should be explained to him, and then he should be allowed to sit quietly in a chair with the mask on and a supply of pure air until the circulation and respiration have settled to their normal values for rest; 10 to 15 minutes is usually sufficient for this purpose. It is also an advantage to supply the patient with some literature to keep his attention occupied during the progress of the test, and incidentally this will help to distinguish those who quickly lose their power of mental concentration at an altitude. Good results may be obtained without any special recording apparatus, by observing the

general condition of the patient, but it is much better to keep a careful record of the respiration, pulse-rate, and blood-pressure, since by these means commencing failure may be recognized earlier, and so the duration of the tests may be shortened. It is inadvisable for many reasons to carry the experiment to the point where complete collapse occurs, and the mask should be at once removed if syncope is imminent. The methods that have been employed for the observation of the patient must therefore be described.

(*a*) *Respiration.*

The respiration has in many cases been recorded by means of a pear-shaped bag strapped over the xiphisternum and connected to a tambour. This method has already been mentioned in connexion with the results obtained with Flack's bag, and on the whole gives a record more or less proportional to the depth of respiration. Its disadvantage lies in the fact that if the respiration becomes very shallow and is costal rather than diaphragmatic, it may be scarcely recorded at all. None the less with most subjects the record is fairly accurate.

More recently the records have been obtained by connecting the expiratory tube of the mask with a delicate tambour. A rubber tube is slipped over the expiratory valve and the outlet is clamped and constricted sufficiently to create a slight positive pressure in the mask and glass reservoir. This should be just sufficient to cause the football bladder to remain half distended without being in any way tense. This degree of resistance to the outflow is insufficient to hamper the patient, and it prevents the mask being sucked forcibly against his face and so makes him more comfortable. In addition, by helping to keep the football bladder partly filled it increases the reserve of air available for the patient, should he want to take a rapid deep breath. The record is then obtained quite easily by letting in a small glass tube into this rubber cap, and connecting with a very delicate rubber tambour. During inspiration the expiratory valve is closed and the tambour registers atmospheric pressure; while during expiration the pressure will vary according to the rate at which the air is expelled. A shallow quick expiration will produce a spike, a deep slow expiration will give a maintained raised plateau; but if the area covered by the curve is measured and not merely the height reached, then the volume of the respiration may be roughly estimated from the curve. Naturally the recording pen must have as little friction as possible, therefore the rod carrying it should be light and flexible.

In practice the records obtained in this way have been found to be useful and reasonably accurate, and, by glancing at the record, an estimate of the respiratory reaction can usually be made. But where the results have been plotted on a curve, considerable labour has been involved. Periods of 15 to 30 seconds have been chosen at intervals of a few minutes at typical parts of the charts, and the rate has been determined by counting the respirations in this period. The average depth of the respirations has then been estimated by finding the average height and average width of the same curves, and then obtaining the product of the two. A more accurate result

might be obtained by taking the product of the height and breadth of each wave separately, but the former method is quicker and sufficiently accurate. If the wave is of the nature of a spike the breadth is taken as that of its midpoint. Finally, all the results have been expressed as a percentage of the respiration seen at the commencement when the patient was receiving pure air.

This method gives a real indication of the changes in the ventilation rate of the patient. This is borne out by the fact that during the preliminary period when the patient receives pure air, the ventilation rate (i. e. the respiration rate multiplied by the average depth) remains usually remarkably constant even when the respiration rate is showing considerable variation, and also by comparing the records of several individuals obtained in this way with the values for their tidal air, &c., obtained by making them breathe into a bag.

(b) Pulse-rate.

This has been taken by hand at frequent intervals, and care is taken to ensure as far as possible that the original pulse-rate is the normal for the patient at rest.

(c) Blood-pressure.

The observations in the blood-pressure changes have been made with the ordinary Riva Rocci apparatus with a mercury manometer, and the recurrence of the pulse has been determined by using a stethoscope over the brachial artery at the elbow, the diastolic pressure being measured at the same time. In arriving at the diastolic pressure the point at which the sounds begin to fade and become distant has been taken as described by Oliver. With most patients this point is very definite and distinct, and any two experienced observers will get identical readings, but there are exceptional cases in whom the different phases are very indefinite. In these individuals the sound heard in the first period is usually hard and sharp, and the maximum loudness occurs very early; as the pressure is allowed to fall the intensity of the sound gradually diminishes, and no definite point can be distinguished where the third phase changes into the fourth. Under these circumstances the reading of the diastolic pressure is uncertain. It is of some interest that it is not uncommon to find an individual who gives a definite diastolic reading at ground levels change so that the sounds become of this abnormal type when he is subjected to oxygen-want, while in other cases the sounds become more complicated and may disappear, to reappear again when the pressure is further lowered. Both these abnormal types have only been observed up to the present time in people who are unfit.

As a general rule we have found the pulse-pressure increased by a lowering of the diastolic pressure, in the reaction to oxygen-want. That the readings of diastolic pressure are correct in these cases is borne out by a more careful examination of the sounds. In a few cases the occurrence of the first sound, the pressure at which the sound is loudest, the point at which it changes from the third to the fourth phase, and that at which all sounds disappear, have

all been noted, and the changes observed as the patient was subjected to oxygen-want; it was found that these sounds were all heard over a greatly increased range, but their relationship to each other

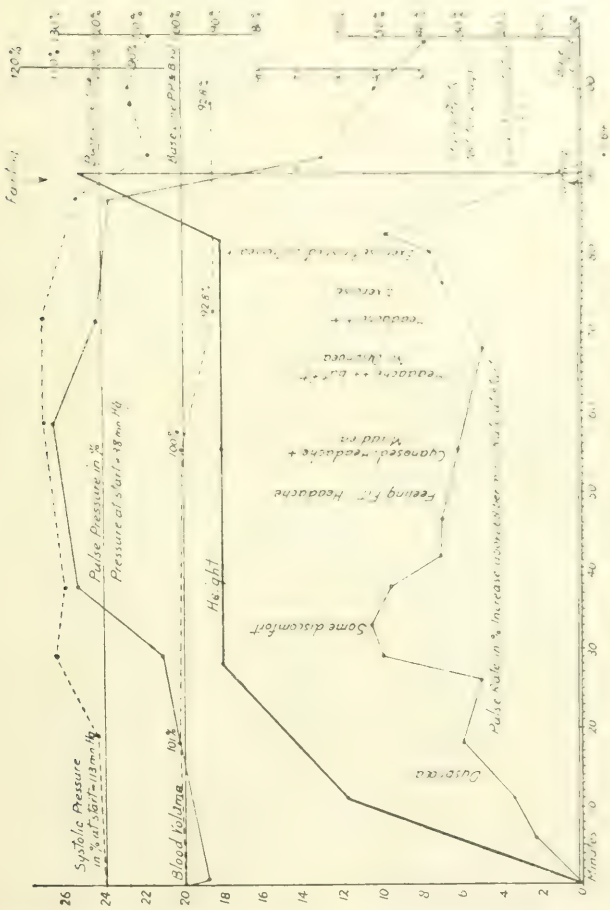
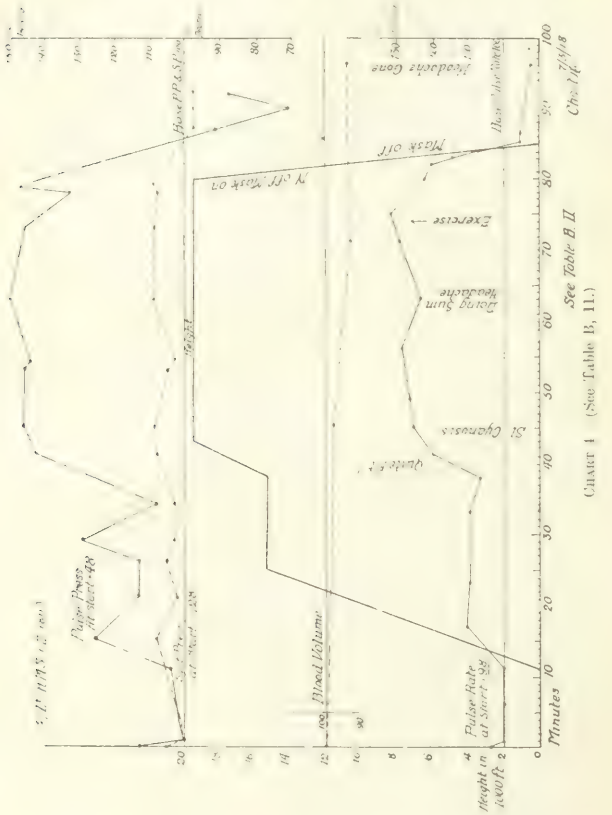


CHART 3. H. C. B. 24/2 18. (See Table B, 5.)

remained unaltered in ordinary normal individuals, and the diastolic pressure was lowered, whichever change in the sound was taken as the indication of the diastolic pressure.

D. The Reaction and its Interpretation.

The individuals tested may be classed roughly into two groups, those able to stand altitude well and those whose reaction is inadequate to enable them to fly at great heights for any length of



time. In the good type there has been recognized a definite reaction both of the respiratory and cardio-vascular systems, although the relative importance of the changes seen in these two systems varies in different individuals. Similarly, the bad type may be subdivided into different groups according to the relative prominence of the changes observed.

(a) The Good Type.

The reactions observed in this type may be seen by reference to Table B, Charts 3, 4, 5, 6, 7, and 8, and Fig. II. Briefly, those in this group can withstand an altitude of 18,000 feet for an hour or more without undue distress. A few cases have complained of headache and others of slight sleepiness. The respiratory reaction was only carefully recorded in five cases. In these the depth was

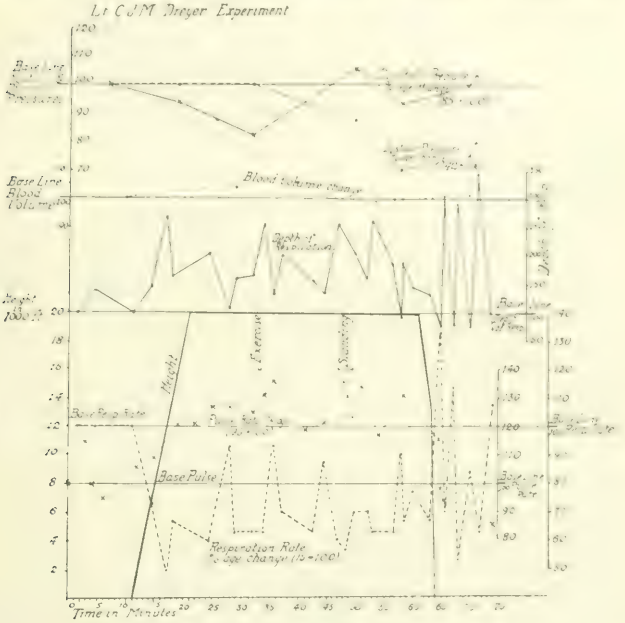


CHART 5. (See Table B, 20.)

increased, slight periodicity was common, and the rate was usually slowed. In one case (No. 44) the rate was also increased, but this officer had done little high flying, and it is doubtful whether he would stand much work at high altitudes (Chart 8). Officers of a good and intelligent type have often found that the dyspnœa experienced at high altitudes may be alleviated by educating themselves to breathe more deeply and slowly when distressed, and there can be no doubt that this is the normal good reaction.

The pulse-rate is increased about 30 per cent. above normal but as adaptation takes place it tends to fall to a slightly lower level: this corresponds to the time at which blood concentration first makes

its appearance. In one case, Table B (42), the altitude reached was only 10,500 feet, with only a slight rise, but it is improbable that the normal individual increases his pulse-rate to any extent at this altitude. At the greater heights (18,000 feet), if the pulse-rate is not increased, unpleasant symptoms are inevitable. Parallel with the

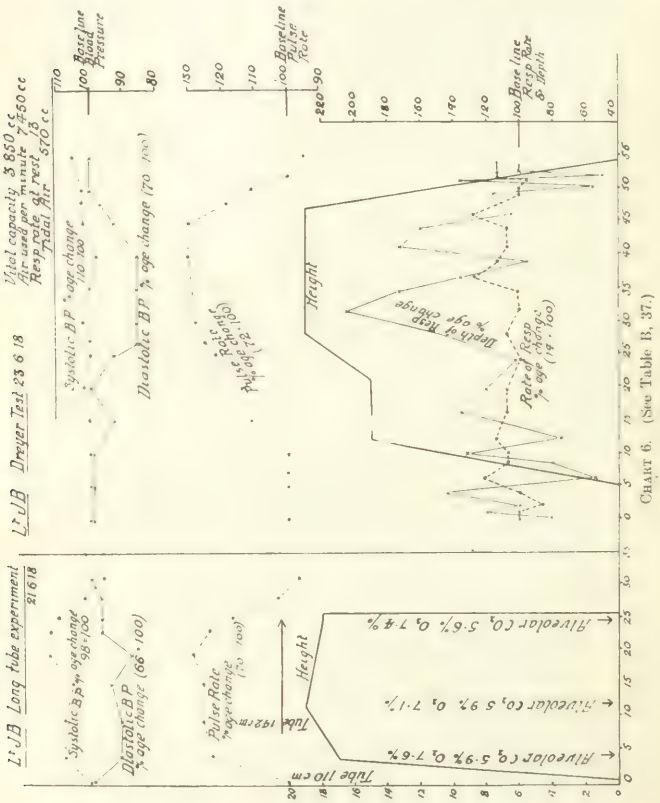

L. J. B. Dreyer Test 25 6 18
Vital capacity 3 850 cc
Air used per minute 7 250 cc
Resp. rate at rest 13
Tidal Air 570 cc
100 Baseline Blood Pressure
100 Baseline Pulse Rate
100 Base line Resp. Rate & Depth
Systolic B.P. % age change (110 · 100)
Diastolic B.P. % age change (70 · 100)
Pulse Rate % age change (72 · 100)
Height
Depth of Resp. % age change
Rate of Resp. % age change (18 · 100)
L. J. B. Long tube experiment 21 6 18
Systolic B.P. % age change (98 · 100)
Diastolic B.P. % age change (66 · 100)
Pulse Rate % age change (72 · 100)
Tube 192 cm
Height
Tube 110 cm
Alveolar CO_2 5.6% O_2 7.4%
Alveolar CO_2 5.9% O_2 7.1%
Alveolar CO_2 5.9% O_2 7.6%

CHART 6. (See Table B, 37.)

rise in pulse-rate there is an increase in pulse-pressure usually brought about by a fall in the diastolic with only a slight rise in the systolic pressure. Where in this class a rise in pulse-pressure has been due mainly to an increased systolic pressure, mental or physical work has apparently been the cause. The diastolic pressure has never in the good type fallen below a level of 60 mm. Hg, and it is probable

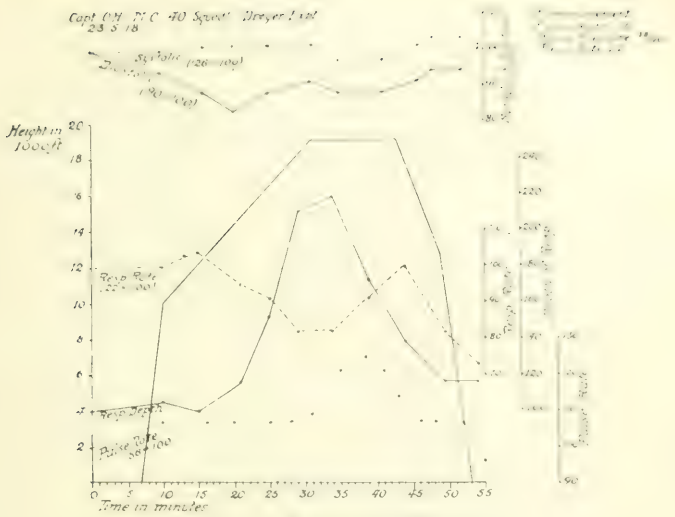


CHART 7. (See Table B, 29, and Fig. 11.)

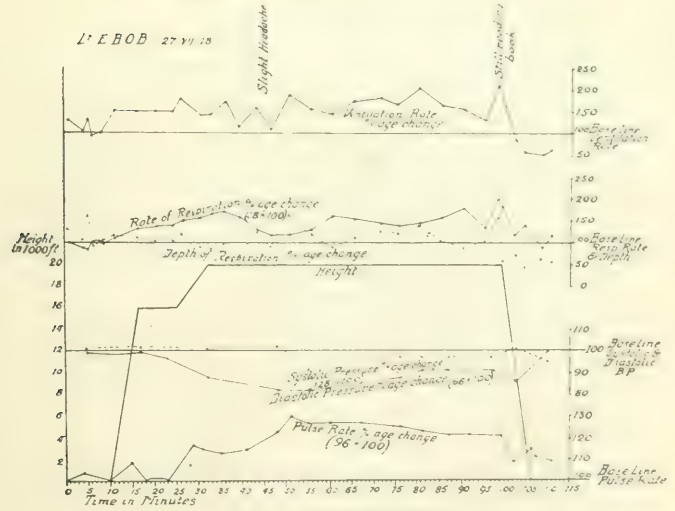


CHART 8. (See Table B, 44.)

that all individuals whose diastolic pressures are normally below this level are incapable of standing high altitudes.

The change in the haemoglobin percentage has been noted in eight cases of this class. From this small number of observations it seems that the blood is rather more dilute during the first fifteen minutes, returns to normal again after about half an hour, and later again undergoes some concentration. Possibly the delay is due to lag in the peripheral circulation.

Considerable after-effects are observed in all individuals who have

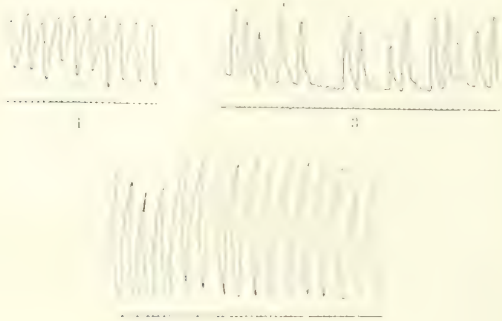


FIGURE II. (See Table B, 29, and Chart 7.)
Respiratory record, bag method.
1. Normal, ground level.
2. After 26 minutes oxygen want, up to 19,000 feet. Depth increased. Rate slightly slowed. Very little periodicity.
3. On return to full air. Periodic breathing with apnoeic pauses.
Time-marker in this and other figures gives 1 sec. intervals.

been subjected to oxygen-want for any length of time. Respiration becomes subnormal both in rate and depth, and usually shows definite periodicity, but not so much as in bad types. Similarly the pulse-rate, systolic pressure, and pulse-pressure all become subnormal, a definite rise occurring in the diastolic pressure. Headache, when present, may persist for some hours, and there is definite fatigue both for mental and physical work.

A few comments may be made about the charts here reproduced. No. 4 is remarkable in that this officer always had a resting pulse of about 100, and yet was able to stand altitudes well, as was shown by the results here charted, and by his previous and subsequent history. Chart 5 shows a similar case, in which the blood-pressure changes are also rather abnormal, but this abnormality was probably due to the exercises he was made to do during the test; in consideration of his previous history and fast pulse these exercises were made unusually severe. Chart 7 shows a rather sluggish circulatory response and a fast initial respiratory rate. This may have been due to the fatigue from which this officer was suffering.

(b) *The Bad Types.*

The bad types may be classed as follows :

1. *Those in which the respiratory reaction is excessive* (Table C,

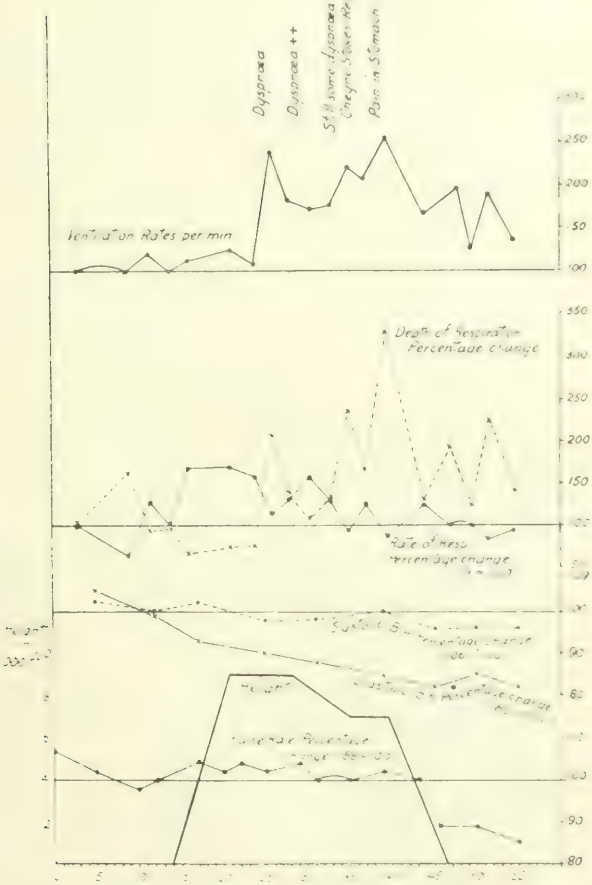


CHART 9. Lt. W. C. F. 19/7/18. (See Table C, 41.)

Charts 9 and 10 and Fig. III) causing dyspnoea, often so pronounced as to necessitate the stopping of the experiment. These individuals react at once to even a slight degree of oxygen-want, and the changes

are always associated with a subnormal vascular response. The increased ventilation is brought about both by an increase of the rate and depth of respiration, the relative importance of the two factors varying in different individuals. Towards the end of the experiment the patient gasps for breath, and breathes very deeply as well as rapidly. The pulse-rate is only temporarily increased if at all, and may show a short but definite acceleration after the nitrogen has been turned off. The systolic and diastolic

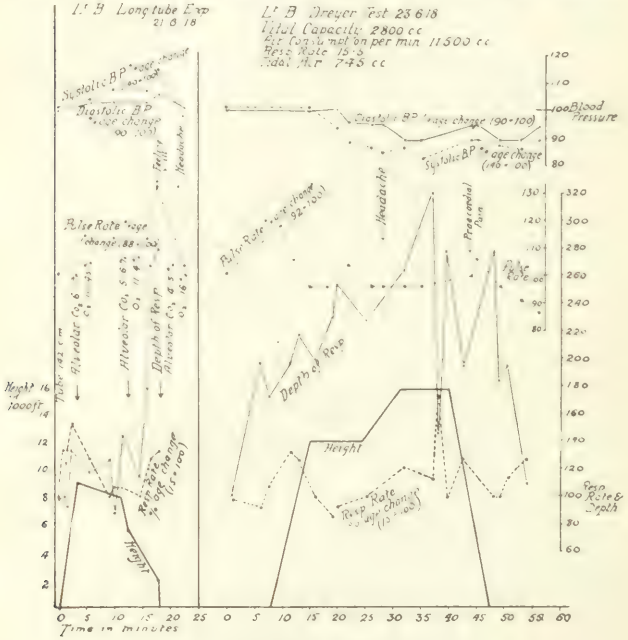


CHART 10. (See Table C, 36, and Fig. III.)

pressures have fallen in every case, while any rise in pulse-pressure reaction is usually temporary.

2. *Those in which the respiratory reaction is subnormal* (see Table D, Chart 11, and Fig. IV). In this group there is usually a temporary increase in ventilation, after which the respiration begins to fail and appears to be insufficient to compete with the abnormal conditions. Similarly the cardio-vascular response is subnormal, the increase in pulse-rate is below the average, little if any increase in pulse-pressure was seen except in one instance (48), and the systolic pressure always showed a tendency to fall. Early syncope occurred in 50 per cent. of the cases.

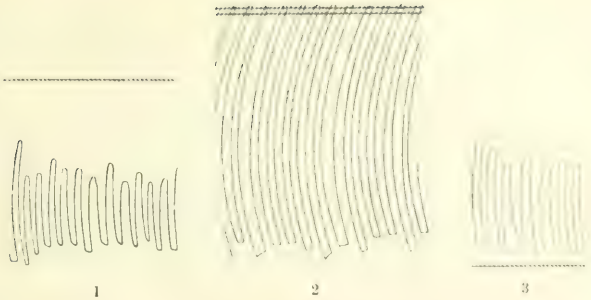


FIGURE III. (See Table C, 36.)
Respiratory record, suction method, normal tambour.

1. Normal, ground level.
2. After 27 minutes oxygen-want, reaching 15,800 feet. Little change in rate. Excessive increase in depth.
3. Seven minutes after return to ground level. Ventilation still above normal.

Note.—In tube experiment he appears to show a quite abnormal washing out of CO_2.

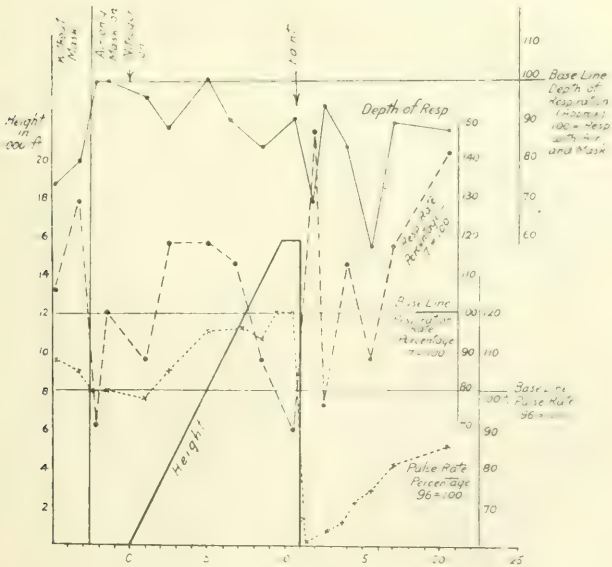


CHART II. Lt. P. E. H. 10/4/18. (See Table D, 17.)

FIGURE IV. (See Table D, 43.)
Respiratory record, suction method, normal tambour.
1. Normal, ground level.
2. After 40 minutes oxygen-want, 19,500 feet. Little change in ventilation.

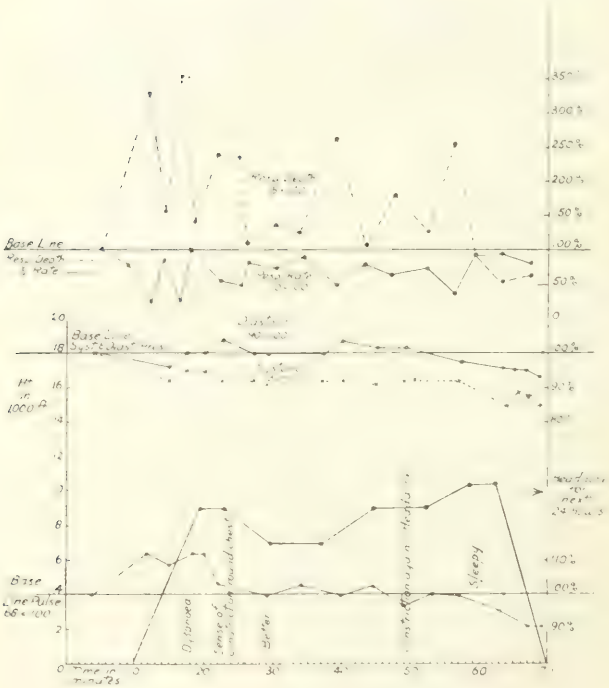


CHART 12. Lt. J. W. 19/7 18. (See Table E, 40.)

It is impossible to say whether the cardio-vascular changes are secondary to the respiratory failure or whether they have a common cause.

3. *Cases in which considerable periodicity in rate or depth of respiration was the most characteristic feature* (see Table E, Cases 12 and 13, and Figs. V and VI); in some of them the ventilation appeared to be diminished while in others it was increased, but the ill effects appeared to be due very largely to its irregularity. Associated with this group all varieties of cardio-vascular response were

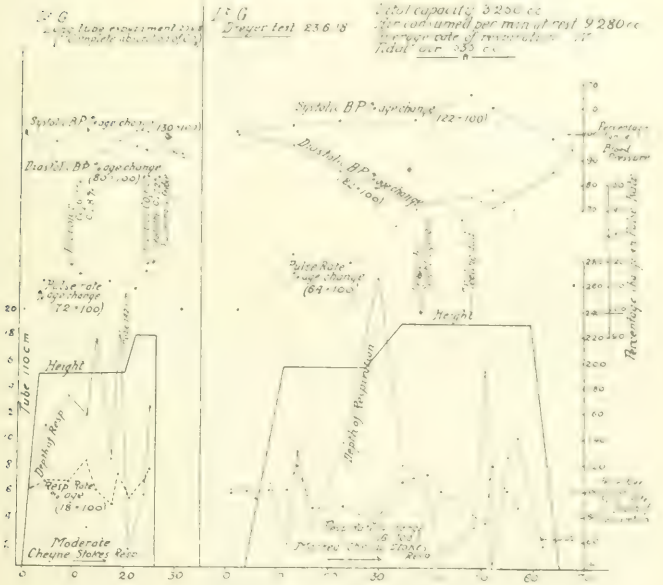

J. G.
Dwyer test 23.6.18
Total capacity 3250 cc
Air consumed per min at rest 9280 cc
Systolic BP % age change (130 = 100)
Diastolic BP % age change (85 = 100)
Pulse rate % age change (72 = 100)
Height
Depth of Respiration
Pulse Rate % age change (64 = 100)
Systolic BP % age change (122 = 100)
Diastolic BP % age change (82 = 100)
Moderate Cheyne Stokes Resp.

CHART 13. (See Table E, 38.)

found, and the cases might be classified under other headings according to their vascular response. In a certain number of them definite variations have been noticed in pulse-rate and blood-pressure corresponding with their apnoeic periods, during which the circulation tends to fail, and in this case it is impossible to give more than a rough approximation of the blood-pressure variations. In one case (10) the periodic breathing which came on at 18,000 feet in the air was so violent as to prevent him keeping his controls steady, and, continuing as he descended, made it very difficult for him to land.

4. *Cases in which the cardio-vascular response seems to be excessive* (see Table F and Charts 14 and 15); of the five cases included

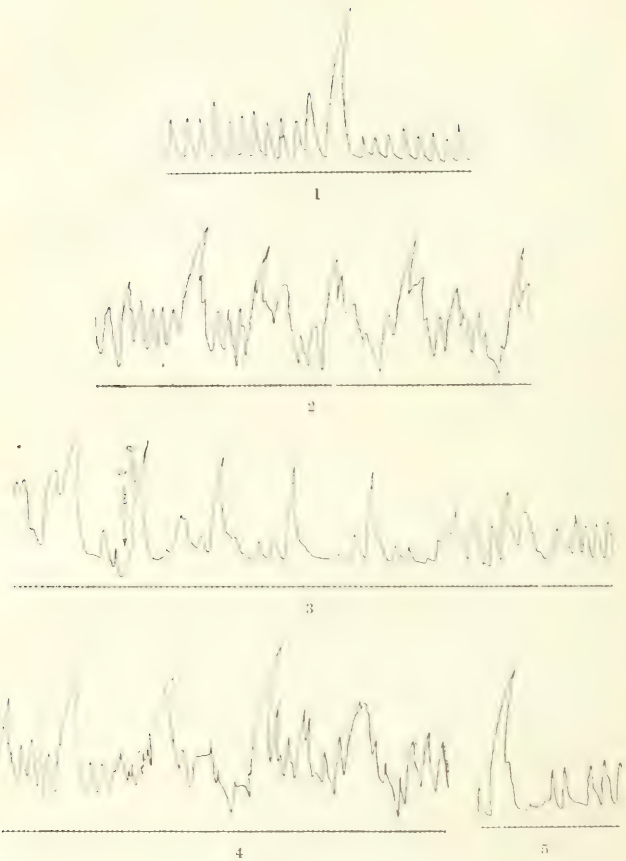


FIGURE V. (See Table E, 21.)
Respiratory record, bag method.

1. Normal, ground level.
2. After 20 minutes oxygen-want up to 19,000 feet. On the point of fainting.
3. Recovering from faint on being brought down to 12,000 feet.
4. Recurrence of faint five minutes later after exercise at 12,000 feet.
5. Ground level half a minute after removal of mask.

Note.—Very irregular periodicity just before syncope and similar relapse after exercise at 12,000 feet.

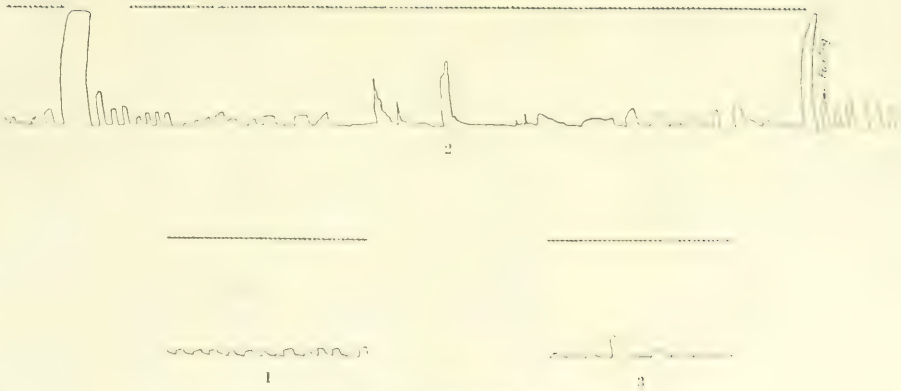


FIGURE VI. (See Table E, 45.)
Respiratory record, suction method, normal tambour.

1. Normal, ground level.
2. After 19 minutes at 17,000 feet. Very irregular periodic respiration with some apnoeic pauses.
3. Immediately on return to ground level.

in this group in only two was the respiration recorded, so that it is only possible in these two cases to state definitely that the respiratory reaction was normal. In this class the increase in pulse-rate was only slightly above the average, but the pulse-pressure was very large, showing an enormous increase unless it had been at a very high level before the experiment started. Taking the normal increase in pulse-pressure at 36 per cent., the average increase in these cases was 61 per cent. This increase was brought about by an increase in systolic as well as by a fall in diastolic pressure. It

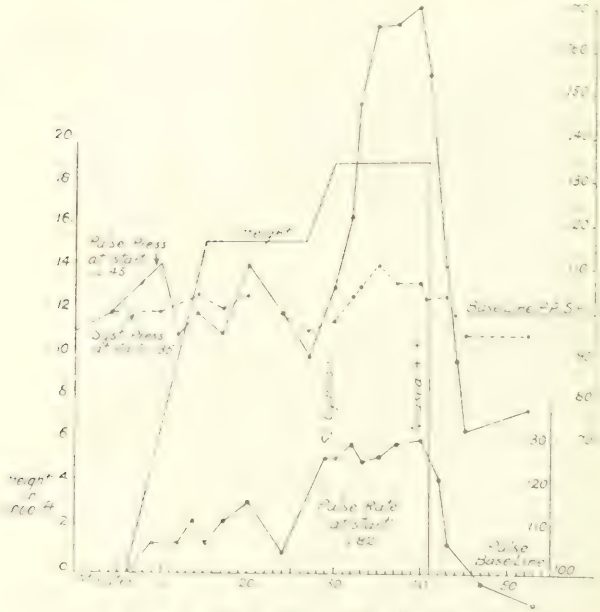


CHART 14. 2 Lt. C. J. H. 14 3 18. (See Table F, 14

is possible that the rise in systolic pressure occurs as an attempt to raise the mean pressure, since in these cases the diastolic pressure falls to a very low level.

5. *Cases in which the cardio-vascular response seems to be subnormal* (see Table G and Charts 16 and 17); of eight cases in this group the respiration was recorded in five, so that it can be definitely stated that this subnormal reaction may be seen associated with a normal respiratory response. On the other hand, cases with a similar cardio-vascular reaction are included in groups 1 and 2, and some occur in group 3. The average increase in pulse-rate was only

13 per cent., but the change in pulse-pressure is not so definitely subnormal. The systolic pressure remained fairly constant. Of the symptoms sleepiness was the most prominent, often associated with little distress, and in some cases scarcely realized by the patient himself.

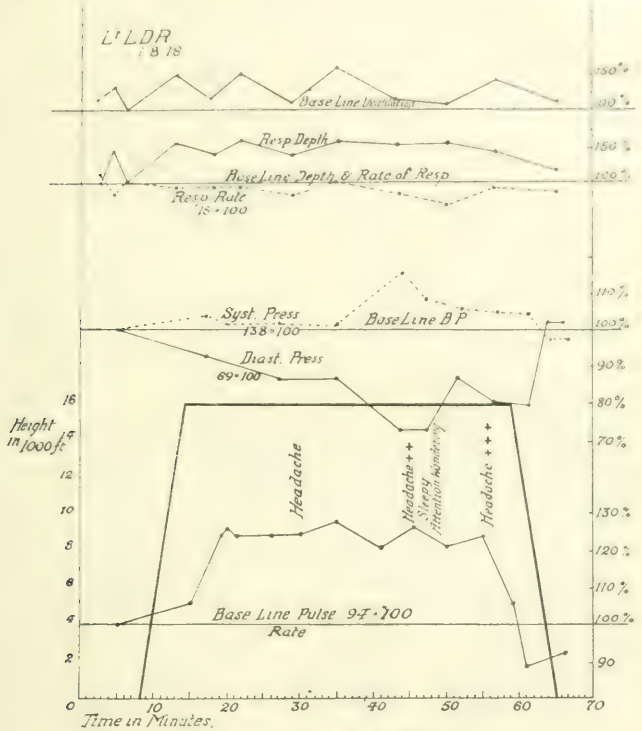


Chart 15. (See Table F, 48.)

This type of case appears to react to altitude by a general lowering of activity, and these symptoms must be regarded of considerable importance because the individuals do not realize how inefficient they are when doing any kind of work on high-flying machines.

Syncope. Actual syncope was not often observed, as the experiment was usually stopped before it supervened. It was noted in eight cases, including cases of every kind of respiratory reaction, but in six out of the eight cases the cardio-vascular response was definitely subnormal from the commencement. Where the blood-

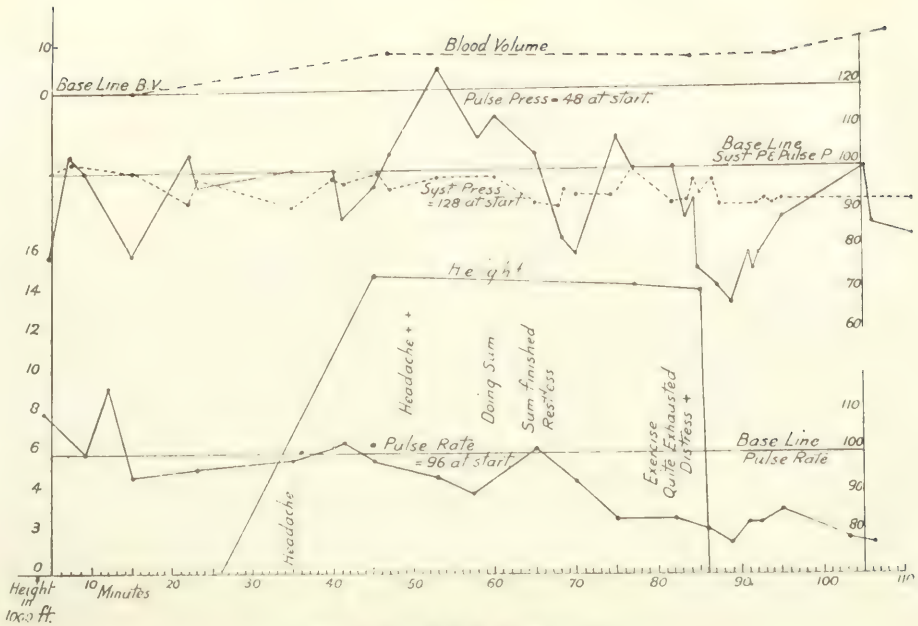


CHART 16. 2/Lt. C. H. H. (See Table G, 12.)

pressure was taken shortly before syncope occurred the pulse-pressure was found to be definitely decreased (the diastolic pressure often rising), followed somewhat later by a fall in systolic pressure. At the onset of syncope a rapid fall of both pressures was observed, but quick recovery was seen as soon as the patient was given fresh air.

Syncope in these cases with low oxygen tensions seemed to be due to cardiac failure, since it was often associated with a slow thready pulse, preceded by a period of gradually becoming pulse-

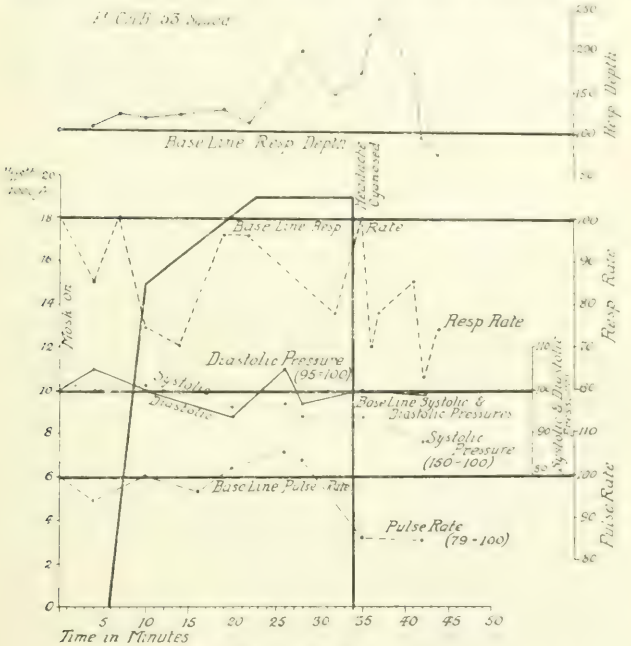


CHART 17. (See Table G 27.)

pressure and raised diastolic pressure. The condition was quite different from the faint of a nervous boy as the result of a medical examination (e.g. taking of blood-pressure), where we can confirm the observations of Cotton and Lewis (5), since we also found in these cases a marked slowing of the pulse accompanied by a great fall in both systolic and diastolic blood-pressures.

Arbitrary Arrangement into Groups. The bad types have been divided into various groups for convenience of description, and to some extent these distinctions are definite. It must, however, be recognized that many cases could be classed into more than one

group, while in other cases it is extremely difficult to decide what is the chief cause of failure. In the cases showing periodic respiration it is often very difficult to settle whether the ventilation is above or below normal, and probably many cases included in this group should properly belong to either the excessive or subnormal respiratory types. Though big differences in sensitiveness to oxygen-want occur, it is impossible to explain them in all cases by an abnormal response of the nervous centres to chemical stimuli, since the cardio-vascular and respiratory responses do not always run parallel. Very few observations on blood-volume changes have so far been made on the bad types, but a few are included in the tables. From these it will be seen that the blood-concentration seen in the first cases did not occur or if present was not maintained. It is possible that blood-volume changes may be of great importance, but time has not allowed any further investigation of this point.

E. Conclusions.

1. The Dreyer method of testing the capacity of airmen to stand diminished oxygen tension is of great practical value and the best so far devised.

2. The normal reaction to oxygen-want corresponding to about 18,000 feet is an increase in pulse-rate of about 30 per cent., of pulse-pressure of about 36 per cent., and after about half an hour some degree of blood-concentration. The pulse-pressure rise is brought about mainly by a fall in diastolic pressure, while the systolic pressure in the absence of mental or physical work is only slightly raised. The respiration is slowed and deepened, increasing the ventilation about 50 per cent.

3. Where failure to withstand oxygen-want occurs it may be associated with an abnormal respiratory response, excessive, subnormal, or periodic, while in other cases the cardio-vascular system seems mainly at fault. In these failure appears to be caused by a subnormal reaction except in a few instances with a very big pulse-pressure in which the diastolic pressure appears to fall to a level so low as to be harmful. It is doubtful whether blood-concentration occurs in cases liable to failure.

4. The symptoms from which the patient has suffered when actually in the air may be reproduced by the Dreyer method, but it is most important to realize that a patient who claims to be perfectly fit at high altitudes may in reality be quite inefficient; sleepiness is the most common symptom and yet is often not recognized by the airman.

5. Symptoms of oxygen-want may even occur in rare cases at altitudes below 10,000 feet, although the individual may appear perfectly healthy.

We are both indebted to Lt.-Col. J. L. Birley for his keen interest and help in the preparation of this paper.

Appendix

In revising this paper before it is reprinted (in 1920) I (H. C. B.) have thought it best to add to it a few extra charts, selected out of a large number which had to be omitted in the original publication owing to the difficulties of reproduction

during the war. After the publication of the report on [illegible] were made, which must also be alluded to; I do not propose to discuss myself in detail since the complete record of the changes observed is not [illegible] so that only the exceptional cases will be discussed at all fully. I also want to take this opportunity to refer briefly to the conclusions drawn by other workers who have recently published results obtained under similar conditions, especially as much of this work appeared at about the same date as our own.

Of the 11 additional tests, 5 had marked periodic breathing with a cardio-vascular response that was more or less subnormal; 3 gave a simple subnormal cardio-vascular response, and 2 a subnormal cardio-vascular response, accompanied in one case by an excessive respiratory response with great increase in the depth of respiration, and in the other with a very shallow but very rapid respiration. The other man gave a normal response. These two last cases are instructive in some respects and consequently protocols are given in some detail, supplying also a fuller indication of the methods employed, though these cases have not been so carefully worked out as the previous ones, and their respiratory records are not now available for accurate analysis.

(1) Lt. S. S. G. 17 hours as observer on day bombers. Shortness of breath and sleepiness at altitudes. Poor physique. Results of respiratory tests given in Report No. 9, Table II, 26 (p. 195).

Time.	*Approximate Altitude.*	*Pulse Rate.*	*Blood Pressure.*	*Remarks.*
2.20	Sea level			Mask on.
2.30	.. .. ..	84		
2.35	.. .. ..	90		
2.38	.. .. ..		116/72	
2.40	.. .. ..	86		
2.41	.. .. ..	..	116/72	
2.42	Rising			Nitrogen turned on.
2.45		78		
2.47	↓		116 to 108 70 to 60	Swinging of blood-pressure, pulse-rate also irregular. Respiration rate increased.
2.49	12,000 ft.	92		
2.51	.. .. ..	92		
2.53	Rising			
2.55	↓		? 106/64	
2.58	↓	103	? 116/60	Headache, sleepy.
3.0	15,000 ft.	102		
3.10	.. .. ..	..	? 106/94	
3.12	.. .. ..	91		
3.15	Rising			
3.19	.. .. ..	96		More sleepy.
3.20	.. .. ..	..	? 106/60	
3.21	.. .. ..	96		Headache bad. Still reading book. Not distressed.
3.26	.. .. ..	94		Put down book. Respiration rate now 52, very shallow and periodic in depth.
3.30	.. .. ..	..	? 110/84	Can hardly keep eyes open. Very dull and sleepy.
3.32	Coming down			Respirations still quicker and becoming periodic also in rate. Rate reaching 72 at times.
3.36	↓ Nearly sea level	72	96/68	Respirations shallow and periodic in rate and depth.

Comments. Increase in respiratory rate very marked. Shallow rapid respiration (28) at normal oxygen tensions and this increased at lower tensions. Very unstable blood-pressure showing big fluctuations, and never staying constant. Increase in pulse-rate up to 20 per cent., but not maintained, and very little change in pulse-pressure. Patient never cyanosed during the test.

This patient, therefore, shows a subnormal cardio-vascular response with an extreme degree of rapid shallow respiration similar to that described by Haldane, Meakins, and Priestley (6).

(2) Lt. G. S. An officer of good type with 110 hours day bombing to his

credit. Found flights trying and attributed it himself to nerve strain. When found unfit to fly at altitudes he transferred to infantry at his own request. Physique very good. Results of respiratory tests given in Report No. 9, Table I, 22.

Time.	*Approximate Altitude.*	*Pulse Rate.*	*Blood Pressure.*	*Remarks.*
2.25	.. .. ..	.. ..	..	Mask on.
2.30	.. .. ..	80	124/80	
2.35	.. .. ..	80	124/80	
2.40	Rising v. rapidly			
2.50	24,500 ft.	112	128/64	Very cyanosed. Headache. Stops reading.
2.53	.. .. ..	120		Respiration deepened. Rate steady
2.54	Coming down			
3.0	18,000 ft.			Less cyanosed. Some headache.
3.5	.. .. ..	81	118/66	Reading again. Deep respirations. Rate steady.
3.10	Rising			
3.13	↓	90		Very cyanosed. Restless. Stops
3.17	24,000 ft.		128/64	reading. Deeper respiration.
3.18	.. .. ..	100		
3.24	.. .. ..	114	146/60	B.P. showing fluctuations.
3.31	Coming down			
3.33	.. .. ..	96		
3.35	.. .. ..	..	120/80	
3.37	.. .. ..	84		
3.43	.. .. ..	84	120/82	

Comments. This case illustrates the immensely rapid changes in oxygen tension that can be endured by a fit man. The 'altitudes' were confirmed by analysis of four samples of the gas mixtures in this case. The respirations were deepened and the rate was throughout steady or slightly slowed. The cardio-vascular response is of interest in that the pulse-rate slowed when the patient was brought to an altitude of 18,600 from a temporary 24,500, so that carrying him to the greater height had perhaps increased his rate of adaptation to the ordinary test level. Also later when he was returned to an altitude of 24,000 the blood-pressure reaction which had been normal in character changed to one with an excessive increase in pulse-pressure judged by tests at lower levels, with an increased systolic, a lowered diastolic pressure, and a commencing instability of both pressures. This suggests that the character of the response is to some extent dependent on the altitude at which the individual is tested relative to the greatest height to which he can readily adapt himself, emphasizing still further the arbitrary character of any division into groups. Possibly the reaction seen at the highest limits tolerated is one in which adrenalin plays a part, corresponding with the results obtained on cats by Kellaway (7).

General Discussion. Various types of respiratory response have been described in this paper and confirmation of Haldane's work on Cheyne-Stokes respiration has been obtained. On the other hand, only a small percentage of the individuals examined showed any great increase in the respiratory rate on exposure to low oxygen tensions, a type of response relatively common among the subjects used by Haldane and his co-workers (6) and (8). In this difference we are in agreement with American workers, who also found the normal reaction to be a deepening of the respiration with the maintenance of a normal rate even on exposure to quite low oxygen tensions (9) and (10).

Haldane and his co-workers in the last paper quoted report a change of the reaction of the urine in an alkaline direction in adaptation to low oxygen tensions. Samples of urine were taken after two of our tests (Tables B 5 and E 6) and were examined for us by Dr. H. Maclean, to whom we are much indebted. In both cases the reaction was found at the extreme range of normal limits of alkalinity. We were unable to continue these determinations through pressure of routine work, and we did not realize their significance at the time, but so far as they go, they bring forward confirmatory evidence of Haldane's theories, and so are mentioned here.

Very similar variations in the character of the [illegible] to low oxygen tensions are reported by American workers using the rebreathing test (9, 10, and 11). Only one considerable [illegible] these workers found that in the good response the diastolic pressure remained steady or was slightly raised, while we have found it lowered, and this, too, in spite of the fact that they also used an auscultatory method for determining the diastolic pressure. The contrast probably depends on the different conditions of the two tests; whereas the American method gradually reduced the oxygen in the air breathed to 8 or 7 per cent., the process requiring 25 to 30 minutes, we reduced the oxygen percentage at once usually to 12 per cent., and often to 10 per cent., and maintained the patient at this level for 40 minutes or longer. In the rebreathing test the subjects were only exposed to oxygen percentages below 12 per cent. for some 10 minutes, and a fall in the diastolic pressure in many cases in the terminal part of the test is reported. Reference to Charts 2, 5, and 6 of the American Air Service Medical Manual shows that this fall commonly commenced at 11 to 12 per cent. of oxygen, so that there is really an agreement with our results, since all our normal cases were maintained at or below this percentage. The case they show in Chart 7 in the same manual is also instructive as to the importance of this fall in diastolic pressure. They note that 'he compensates in some way but does not do it in the usual way'. He commenced with a pulse-rate of 90 to 96 and a blood-pressure of 110/68 to 118/70; with 13 per cent. oxygen the pulse-rate is 87 and the blood-pressure 130/70, and with 7·5 per cent. oxygen the pulse-rate is 90 and blood-pressure 126/58. This case showed then an increase in pulse-pressure of 51 per cent., and may have been even greater since the fluctuations of pressure before the test suggest that the 'normal' pressure may have been altered by excitement. That adaptation can occur with an increase in pulse-pressure though raising of the systolic or lowering of the diastolic pressure seems to be sustained by their results as well as ours, always excepting cases where the diastolic pressure falls to a seriously low level.

More recently Lutz and Schneider (12) have published further data using low pressure chamber, rebreathing apparatus and Dreyer's method, and they too have found a lowering of the diastolic pressure and an increased pulse-pressure, when the oxygen tension is held at a low level. Gregg, Lutz, and Schneider (13) record haemoglobin changes similar to ours. Lutz and Schneider also describe a later diminution of the increase in the pulse-pressure as adaptation to the low oxygen tensions is developed; our results certainly favour such a conclusion (see Charts 3, 6, and 7) but we did not have enough evidence to make any definite statements. The same workers find syncope preceded by a fall in both diastolic and systolic pressures; this we have found also in four of our cases of syncope, but in three others in which the pressure changes were more continuously observed, the earliest sign appeared to be a decrease in pulse-pressure generally accompanied by a rise of diastolic pressure, which then develops into the fall. Examples of this may be given shortly.

Lt. H. (Table G 12) commenced with a blood-pressure of 128/80; at 14,600 ft. after 30 minutes his pressure was 126/66, after 51 minutes 128/80; he was then given some exercise and after this felt very faint and the last blood pressure record preceding the fall was 120/84. In another patient (one of the later additional cases, Lt. D.) the original blood-pressure was 110/70 and the pulse-rate 80. After 28 minutes at 15,000 ft. it was 114/60 and the pulse-rate 90 to 96 and very irregular. He had praecordial pain; after 31 minutes it was 106/56 with a pulse-rate of 88 and after 38 minutes he began to faint. The last record before the fall was rate 88 and very irregular, blood-pressure 106/80.

The agreement between the results obtained by these American workers and our own is the more remarkable in that their tests were performed on recruits, and ours on officers admitted to hospital suffering from slight staleness, severe fatigue, or other conditions due to flying.

Some apology is necessary for the expression of oxygen tensions as changes in altitude or in oxygen percentage. No accurate record was kept of tensions since we were concerned with gross differences between individuals, and to facilitate the disposal of patients all our results were expressed in altitudes. Haldane and his co-workers (8) suggest that any oxygen tension produced by dilution with nitrogen is a severer test than the same tension produced by a lowering of the atmospheric pressure, owing to the nitrogen hindering the diffusion of oxygen. If this is so, then our patients were exposed to a severer test than

is indicated by the charts, but it is remarkable how accurately experienced pilots were able to gauge the 'height' to which they were exposed. Haldane in the same paper also states that owing to the effect of the CO_2 content of blood on the dissociation curve of oxyhaemoglobin, adaptation to low oxygen tensions cannot be brought about by mere changes in the respiration and circulation rate. This does not seem to be supported by our results, since the efficiency of the individual at low oxygen tensions ran more or less parallel with the reactions of the circulatory and respiratory systems. We have drawn attention to the slowing of the pulse, as the blood concentration commences, and this concentration may perhaps be associated with the secretion of alkali by the kidney, but the initial response is effected by the circulation and respiration. Possibly in spite of a more rapid circulation and a lowered CO_2 content, the reaction of the blood in certain tissues is maintained normal by other factors, so that the oxygen is given up readily.

That the more slowly developed methods of adaptation are the more effective however, seems to be supported by the improvement in the symptoms, which often occurs after about 30 minutes, and by the fact that the severity of the test is very much lessened, if the oxygen percentage is lowered more slowly.

The charts have been expressed in percentage changes rather than in absolute figures. This has received some criticism, and has objections in that the actual value of the mean pressure is of considerable importance and is not easily deduced from the charts. But this method was adopted in order to compare men of different initial conditions—for instance subject 2 (Table B) had a rise of pulse-rate of 16 beats per minute, while subject 20 (Table B) had an increase of 33 beats per minute; but on the percentage basis the difference was only one between 31 per cent. and 35 per cent., and this seemed most nearly to express the real difference. A further examination of the figures obtained, a consideration of the evidence they give of the vascular changes involved and of the probable effect on the circulation rate, is in course of production and will be published later.

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(12) Lutz and Schneider, *American Journal of Phys.*, 50, p. 228, 1919.
(13) Cotton, Lutz, and Schneider, *American Journal of Phys.*, 50, p. 216, 1919.

TABLE B. DREYER'S METHOD—NORMAL RESPONSE

Number and Name.	*History.*	*Duration of Test.*	*Height of Test in Feet.*	*Pulse Rate Change.*	*Systolic Pressure Change.*	*Diastolic Pressure Change.*	*Pressure Pulse Change.*	*Blood Volume Change. (Time in Min. from Time N turned on)*	Symptoms. *Respiration Change.*	*Head-ache.*	*Sleepi-ness.*	*Dyspnœa*	*Syncope.*	*Remarks.*
1. B. E. B. 11-2-18	Just completed 300 hrs. flying at 18-20,000 ft. Now a little stale. Physically very fit.	35′	21,000	68 ↓ 84 (24 %)		--		100 ↓ 102 (16′) ↓ 100 (45′)	—	—	—	—	—	Hands and feet cold—fairly fit. Due for H. E
2. F. N. J. 13-2-18	M.O. Healthy. Has never flown.	25′	23,000	64 ↓ 84 (31 %)		-	—	—					·	Pale faint towards close.
3. G. P. 14-2-18	Scout pilot. 56 hrs. Noticed slight dyspnœa above 12,000 ft.	40′	21,500	60 ↓ 80 (33 %)			—	100 ↓ 100 (26′) ↓ 102 (45′)	Deepening with periodic breathing above 19,000 ft. (No record.)	—	—		—	Has done very well since, but mostly low work. Awarded M.C
4. T. T. C. 22-2-18	Observer. Extreme coldness of extremities above 12,000 ft.	46′	21,000	84 ↓ 108 (29 %)				100 ↓ 97 (44′) ↓ 96 (53′)		—	·			No coldness of extremities during experiment. Two days.
5. H. C. B. 24-2-18	M.O. Had not flown. Healthy.	84′	18,000 later 24,500	68 ↓ 104 (53 %)	113 ↓ 129 (14 %)	75 ↓ 83 ↓ 75	38 ↓ 50 (34 %)	100 ↓ 101 (14′) ↓ 100 (51′) ↓ 93 (68′) ↓ 93 (94′)	Deepening. (No record.)	·	—		· at the greater heights	At 18,000 ft. [illegible] was taken. Test [illegible] repeated with time of blood [illegible]

TABLE B (*continued*)

Number and Name.	*History.*	*Duration of Test.*	*Height of Test in Feet.*	*Pulse Rate Change.*	*Systolic Pressure Change.*	*Diastolic Pressure Change.*	*Pulse Pressure Change.*	*Blood Volume Change. (Time on Mask from Time N turned on.)*	*Respiration Change.*	Symptoms. *Headache.*	*Sleepiness.*	*Dyspnœa.*	*Syncope.*	*Remarks.*
7 J. H. H. 1-3-18	Pilot. 30 hrs. Suffering slightly from nervous shock. No symptoms in air. ? Aggravated by oxygen-want.	43′	18,500	54 ↓ 88 (63 %)	132 ↓ 146 (11 %) ↓ 132	82 ↓ 64	50 ↓ 72 (44 %) ↓ 68 (36 %)	100 ↓ 100 (35′) ↓ 106 (51′) ↓ 100 (62′)	Deepening. (No record.)	+	+	—	—	Given sick leave but not returned.
11. H. M. S. 7-3-18	Observer. Malarial history. Persistent tachycardia. Feels quite fit. Bad physique.	69′	19,600	98 ↓ 129 (32 %)	128 ↓ 110 (9 %)	80 ↓ 63 ↓ 70	48 ↓ 72 (50 %)	100 ↓ 98 (34′) ↓ 94 (60′) ↓ 95 (85′)	—	+		—	—	Subsequently did very stout work in Bristol Fighter Sqdn. for many months. Since killed in action. Note rise in pulse-rate from high level.
16. C. F. C. 4-4-18	Scout pilot. 125 hrs. Recently fainted after landing.	45′	19,000	68 ↓ 86 26 %)	110 ↓ 126 (15 %)	70 ↓ 60	40 ↓ 66 (50 %)	100 ↓ 109 (41′)	—	—	—	—	—	Very tired on admission to hospital. BP—95/70. Recovered. Sent to England.

20. C. J. M. 20-4-18	Observer. 200 hrs. Excitable Irishman. Previously turned down by Comms. Board as Pilot.	53′	20,000	96 ↓ 129 (35 %)	142 ↓ 142 ↓ 125 (after exercise)	85 ↓ 70 ↓ 90 (after exercise)	62 ↓ 72 (16 %) ↓ 35 (after exercise)	100 ↓ 104 (16′) ↓ 99 (41′) ↓ 101 (58′)	Deepening shown mild periodicity. 40% increase in ventilation.	—	—	—	—	Just completed long spell of heavy work on Brist. Fighters. Subsequently passed fit as Pilot by Comms. Board. Note rise in pulse-rate from high level.
29. O. H. 23-5-18	Scout pilot. 190 hrs. Recent severe attack of pain left scapular region at 18,000 ft. Shaky on landing.	46′	19,000	56 ↓ 70 (25 %)	128 ↓ 132	90 ↓ 75 ↓ 85	38 ↓ 55 (45 %)	—	Depth increased. Rate slowed. No periodicity. Ventilation about 60 % increase.					A good deal of insomnia recently. Very tired. Fine type. To England. (See Fig. II.)
37. J. B. 23-6-18	Pilot. Passed unfit for flying out here 6 mons. previously. Oxygen-want at 9,000 ft. Immature.	49	19,000	72 ↓ 94 (30 %)	110 ↓ 112	70 ↓ 60	40 ↓ 52 (30 %)	—	Rate slight increase. Depth increased, moderate periodic breathing. Ventilation about 50 % increase.		—			Been at various altitudes on various occasions with much exercise. Passed fit below 10,000 ft.
42. R. J. T. W.	Pilot. No flying in France. Height neurosis.	66′	10,500	68 ↓ 74 (9 %)	108 ↓ 114	60 ↓ 64	48 ↓ 52 (8 %)	—	Changes slight.	Slight				Sent to medical flight.
44. E. B. O. B.	Pilot. 80 hrs. on Bristols. Praecordial pain and dyspnoea above 10,000 ft.	87′	20,000	96 ↓ 124 (29 %)	128 ↓ 130 ↓ 124	66 ↓ 54	62 ↓ 76 (23 %) ↓ 64		Increased rate. Ventilation about 60 % increase.	Slight				Excitable pessimistic neurotic. Invalided 29 years for heart. Cyan.

TABLE C. DREYER'S METHOD—PERIODIC RESPIRATORY RESPONSE

Number and Name.	*History.*	*Duration of Test.*	*Height of Test in Feet.*	*Pulse Rate Change.*	*Systolic Pressure Change.*	*Diastolic Pressure Change.*	*Pulse Pressure Change.*	*Blood Volume Change.*	*Respiration Change.*	Symptoms. *Headache*	*Sleepiness.*	*Dyspnœa.*	*Syncope.*	*Remarks.*
3. C. W. P. 12-3-18	Observer. 35 hrs. Fainted at 15,000 ft. Recovered and fainted again at 16,700 ft. Remembers little till he landed.	21′	19,200	78 ↓ 94 (20 %)	122 ↓ 115	85 ↓ 68 ↓ 85	37 ↓ 55 (49 %) ↓ 33	—	Rate increased over 200 %. (No record.)	+	+	++	?	Constant swinging of diastolic pressure under test. On ground normal reaction of B.P. to exercise much exaggerated. Passed fit night bombers only. Did excellent work 4½ months and then sent home to learn to fly
36. C. R. B.	Pilot Scouts. 40 hrs. Definite O_2 want at 10,000 ft. Thought to be malingering by C.O.	39′	12,000 ↓ 15,800	92 ↓ 105 ↓ 88	140 ↓ 115	90 ↓ 80	50 ↓ 35	—	Rate and depth both increased. (Depth + +).	?	—	+ +	—	Excitable type. A fine pilot. Passed fit below 10,000 ft. (See Fig. III.)
41. W. C. F.	Pilot. 3 hours in France. Concussion 3 months ago. O_2 want at 9,000 ft.	32′	9,000 ↓ 7,000	88 ↓ 92 ↓ 90	106 ↓ 108 ↓ 104	80 ↓ 68	26 ↓ 38	—	Depth much increased. Rate slightly increased.	—	—	+ +	—	Very poor physique. Eustachian obstruction. Thickened M.T. and impaired movement of ossicles. Sent to England. (See Chart 2.)
49. H. J. F.	Pilot. 70 hours in France. Praecordial pain at 18,000 ft. Shortness of breath on ground lately.	26′	18,600	96 ↓ 110 ↓ 104	118 ↓ 106	72 ↓ 58	46 ↓ 56 ↓ 48	—	Depth much increased. Rate showing little change except periodicity.	?	—	?	—	Restless. D.A.H. type of pulse. Found permanently unfit for flying.

TABLE D. DREYER'S METHOD—SUBNORMAL RESPIRATORY RESPONSE

Number and Name.	*History.*	*Duration of Test.*	*Height of Test in Feet*	*Pulse Rate Change.*	*Systolic Pressure Change.*	*Diastolic Pressure Change.*	*Pulse Pressure Change.*	*Blood Volume Change.*	*Respiration Change.*	Symptoms. *Headache.*	*Sleepiness.*	*Dyspnœa.*	*Syncope.*	*Remarks.*
17. P. E. H. 10/4/18	Pilot. 50 hrs. in France. Fainted at 14,000 ft. Recovered at 4,000.	11′	15,800	96 ↓ 115 (20 %)	—	—	—		Depth decreased. Rate increased at first, but later below normal. Marked periodicity in after-reaction.		-	-	-	Polygraph record of pulse-rate changes. Excitable type, flushes easily. Also tested on Flack's Bag (See Chart 3.) Boarded permanently unfit flying; 91 G.S.
18. G. E. H. McE.	Pilot Scouts. Very fine type. 215 hours in France. Gassed Nov. 1915. Occasional attacks of asthma since. Now very tired.	32′	18,000	69 ↓ 84 (22 %)	118 ↓ 118 ↓ 100 ↓ 88	85 ↓ 85 ↓ 70 ↓ 60	33 ↓ 33 ↓ 30 ↓ 20	—	Slower rate. Depth increased at first, but soon becoming subnormal. Very incomplete record	—	—		-	Unexpected sudden onset of fainting. Note fall of systolic and pulse pressures indicating onset of syncope. Has been home and out again, and is now [illegible] getting [illegible] pounds [illegible] week. [illegible] Massage. Has [illegible] [illegible] 40 [illegible] 50 F.A.

TABLE D (*continued*)

Number and Name.	*History.*	*Duration of Test.*	*Height in Feet.*	*Pulse Rate Change.*	*Systolic Pressure Change.*	*Diastolic Pressure Change.*	*Pulse Pressure Change.*	*Blood Volume Change.*	*Respiration Change.*	Symptoms. *Headache.*	*Sleepiness.*	*Dyspnœa.*	*Syncope.*	*Remarks.*
26. T. R. D.	Pilot. 8 hours in France. O want at 10,000 ft. Shortness of breath.	25′	17,300	74 ↓ 79 (7 %)	120 ↓ 100	85 ↓ 60	35 ↓ 40	-	Diminution in depth without increase in rate. Some periodicity.	-				Found permanently unfit for flying. Fit G.S. on ground.
33. C.K.H.D.	Pilot. 500 hours in France. Now doing special work. Very tired and not standing height as well as he did.	27′	17,000	68 ↓ 82 (21 %)	100 ↓ 88	65 ↓ 55	35 ↓ 33	—	Rate and depth unchanged. Irregular rather than periodic.	-			:	
34. A. N. O.		59′	18,500	58 ↓ 72 (24 %)	110 ↓ 98	60 ↓ 58 ↓ 64	50 ↓ 34	—	Rate not increased. Transient increase depth, then subnormal. Some periodicity, especially in after reaction.	—	+	—	—	
43. J. H. G.	Observer. 50 hrs. in France. Recent syncope in air after a fight. Previous to this had been getting symptoms of O_2 want.	46′	15,000 ↓ 20,000	68 ↓ 78 (16 %)	110 ↓ 115 ↓ 108	80 ↓ 50	30 ↓ 58	—	Rate subnormal. Depth increased periodically, but insufficient to balance diminished rate.	—	+	—	—	Passed fit night bombers only (See Fig. IV.)

TABLE E. DREYER'S METHOD—PERIODIC RESPIRATORY RESPONSE

Number and Name.	*History.*	*Duration of Test.*	*Height of Test in Feet.*	*Pulse Rate Change.*	*Systolic Pressure Change.*	*Diastolic Pressure Change.*	*Pulse Pressure Change.*	*Blood Volume Change (Time in brackets.)*	*Respiration Change.*	Symptoms. *Headache.*	*Sleepiness.*	*Dyspnoea*	*Syncope.*	*Remarks.*
10 A. S. K.	Pilot (test). 220 hours in France. At 18,000 ft. had attack of severe periodic breathing, so that machine got out of control. On landing had to be helped from machine.	57′	18,000	60 ↓ 81 (35 %)	126 ↓ 122	84 ↓ 68	42 ↓ 56 (33 %)	100 ↓ 102 (30′) ↓ 100 (50′) ↓ 94 (73′)	Excessive periodic breathing after 25 min., lasting for 20 min. after return to full air	+	+	+ +	—	Has since done very good work in DH squadron, but always uses oxygen and has had no recurrence of attack. Awarded M.C. Since wounded
19. E. A. M.	Pilot. 160 hours in France. When diving rapidly from 18,000 9,000 ft. felt sick and vomited at 2,000 ft. Very dizzy. Crashed into another machine on landing.	30′	18,000	80 ↓ 100 (25 %)	114 ↓ 120	78 ↓ 56	36 ↓ 62 (72 %)	—	Excessive periodic changes in rate, less periodicity in depth. Ventilation decreased.	+	—	+	—	Returned to duty. M.O. asked to watch him. Did well, but since missing
21. C. A. M.	Pilot. 10 hours in France. Gasps for breath above 12,000 ft. Has nearly fainted 3 times at 18,000 ft.	29′	18,000	78 ↓ 92 (18 %)	130 ↓ 132	78 ↓ 56	52 ↓ 76 (46 %)		Subnormal, with periodicity very irregular at onset of syncope			—	+	[illegible] hours [illegible]

TABLE E (*continued*)

Number and Name.	*History.*	*Duration of Test.*	*Height of Test in Feet.*	*Pulse Rate Change.*	*Systolic Pressure Change.*	*Diastolic Pressure Change.*	*Pulse Pressure Change.*	*Blood Volume Change. (Time in brackets.)*	*Respiration Change*	Symptoms. *Headache.*	*Sleepiness.*	*Dyspnœa.*	*Syncope.*	*Remarks.*
23. G. H. R.	Pilot. 13 hours in France. Aged 18. Very immature. Severe attack pleurodynia after flying. Had been working 11 hours a day for a year in factory before joining.	35′	15,000	74 ↓ 92 ↓ 72	85 ↓ 88–104 (swinging)	65 ↓ 58–70 (swinging)	20 ↓ ?	—	Rate slowed; marked periodicity in depth, lasting 25 min. after end of experiment.	+	–	+	—	Pulse on admission was 55 sitting, 100 standing, and 112 exercise; typical of exhaustion. During test remarkable swing of blood-pressure never constant. To England.
25. A.H.S.M.	Pilot Scouts. 46 hours. Symptoms oxygen-want at 11,000 ft.	12′	13,000	84 ↓ 80 ↓ (126 on coming down)	148 ↓ 135	95 ↓ 85	50 ↓ 50	—	Rate and depth increased, especially towards end. Definite periodicity (not shown in Chart).	—	–	+ +	—	Passed for below 10,000 ft. Has done mostly ground work since discharge; still has marked aversion to flying above 1,000 ft. ? Neurosis. Is going to infantry at own request.
28. C. R. B.	Pilot. 15 hours in France. Dived from 10,000 to 8,000 ft. very fast. Lost consciousness, but recovered at 500 ft.	38′	18,000	68 ↓ 98 (44 %)	120 ↓ 125 ↓ 106	85 ↓ 68 ↓ 70	35 ↓ 57 ↓ 36	—	Rate slowed; periodicity and diminution of ventilation.	—	–	+	—	Went back to duty, but now always auto-inflates his ears when diving. No recurrence of syncope. Readmitted later and sent home for enucleation of tonsils.

31. W. H. R	Scout pilot. 100 hours in France. 6 weeks' headache, dyspnoea, and vertigo at 12–15,000 ft.	60′	19,500 (max.)	63 ↓ 83 (31 %)	148 ↓ 138	80 ↓ 54	68 ↓ 84 (24 %)	—	Rate slowed; periodicity + in depth. Ventilation diminished.	—	+	—	—	Instructed always to use O_2. Since broken down completely. To Canada.
38. F. R. G.	Pilot. 12 hours in France. Symptoms of O want above 10,000 ft.	61′	19,000	64 ↓ 95 (1 8 %)	122 ↓ 140 (15 %)	82 ↓ 58	40 ↓ 78 (95 %)	—	Periodicity in rate and depth, especially depth.	+	+	—	—	To have oxygen set fixed if necessary.
39. Sgt. S.	Observer. 38 hours in France. Symptoms of O_2 want at 17,000 ft	55′	10,500	69 ↓ 88 ↓ 77	104 ↓ 120 ↓ 114	38 ↓ 86 ↓ 74	38 ↓ 34 ↓ 40	—	Periodicity in depth.	+	+			Periodic breathing and mental dullness in spite of low height. To fly below 10,000 ft.
40 J. W.	Pilot. 30 hours in France. Symptoms of O want above 9,000 ft.	60′	10,500	69 ↓ 76 ↓ 68	130 ↓ 120	90 ↓ 94 ↓ 88	40 ↓ 24 ↓ 32	—	Rate very subnormal. Periodicity in depth. Long apnoeic periods.	+	+	+ early stages	—	Praecordial pain. To Medical Squadron (See Chart 4)
45. W. H. G.	Pilot. 5 hours in France. Symptoms of O want at 13,000 ft. Dizziness, inclined to syncope. Has Eustachian obstruction.	22′	17,000	68 ↓ 96 (41 %)	118 ↓ 124 ↓ 95	76 ↓ 80 ↓ 50	42 ↓ 44 ↓ 45	—	Rate fast, 26 per min., showing little change in depth. Marked periodicity in depth	—	+	—	+	Extra systoles disappearing during test. Sent to England Eustachian obstruction to be treated. Last night bombers only (See Fig. VI)

TABLE E (*continued*)

Number and Name.	*History.*	*Duration of Test.*	*Height of Test in Feet.*	*Pulse Rate Change.*	*Systolic Pressure Change.*	*Diastolic Pressure Change.*	*Pulse Pressure Change.*	*Blood Volume Change. (Time in brackets.)*	*Respiration Change.*	Symptoms. *Headache.*	*Sleepiness.*	*Dyspnœa.*	*Syncope.*	*Remarks.*
46. J. H. G.	Pilot. 5 hours in France. History of symptoms of O_2 want in England at 9,000 ft. Dizziness, headache, &c.	36′	10,500 ↓ 16,000	64 ↓ 77 (20 °/₀)	116 ↓ 114 ↓ 112	78 ↓ 74 ↓ 92	38 ↓ 42 ↓ 20	—	Periodicity in rate and depth, changing to respiration of Class 1.	+	—	+	+ early	At 10,500 periodicity of rate, deep slow respirations, ventilation changing at 16,000 to very rapid deep breathing. Recommended for sea-planes.
47. B. P.	Pilot. ½ hour in France. History of concussion in September 1917. O_2 want above 5,000 ft., severe at 10,000 ft.	76′	11,000 ↓ 16,000	68 ↓ 76 (12 °/₀)	138 ↓ 146 ↓ 136	66 ↓ 58 ↓ 62	72 ↓ 88 ↓ 74	—	Periodicity in rate and depth, with diminution of ventilation.	—	+ +	—	—	Abdominal pain and some nausea. Big respiratory variations in blood-pressure. Periodic breathing started at 11,000 ft. Disability associated with temperamental unfitness. Unlikely to be of any value in air.

TABLE F. DREYER'S METHOD—EXCESSIVE CARDIO-VASCULAR RESPONSE

Number and Name.	*History.*	*Duration of Test.*	*Height of Test in Feet.*	*Pulse Rate Change.*	*Systolic Pressure Change.*	*Diastolic Pressure Change.*	*Pulse Pressure Change.*	*Blood Volume Change. (Time in brackets.)*	*Respiration Change.*	SYMPTOMS. *Headache.*	*Sleepiness.*	*Dyspnoea.*	*Syncope.*	*Remarks.*
6. W. J. S.	Observer. 55 hrs. France. Cannot work at altitude (without oxygen.	61′	20,000	84 ↓ 106 (26 %)	133 ↓ 125 ↓ 147	88 ↓ 65 ↓ 58	45 ↓ 60 ↓ 89 (98 %)	100 ↓ 102 (55′)	Not recorded. Deep breathing and dyspnoea.	+	-	-		Returned to duty, always to use oxygen. Did quite well. Missing 3 months later.
14. C. J. H.	Pilot Scouts. 70 hrs. Vomiting in air above 12,000 ft. during previous month. Very fatigued on landing.	37′	19,000	82 ↓ 107 (30 %)	135 ↓ 150	90 ↓ 68	45 ↓ 77 (71 %)	—	Not recorded.	—	—	—	—	Sudden nausea at end of experiment necessitating removal of mask. Passed fit as test pilot below 10,000 ft. (See Chart 5.
15. J. G. B.	Pilot Scouts. 170 hours. France. Symptoms of oxygen-want at 15,000 ft. and over.	46′	19,000	88 ↓ 132 (50 %)	125 ↓ 137	75 ↓ 50	50 ↓ 82 (64 %)	—	Not recorded.	+				Recommended for training on 2-seater, preferably night bomber.
24. H.E.F.S.	Pilot. 33 hrs. France. Oxygen-want at 14,000 ft. Very sleepy.	37	19,000	64 ↓ 92 (44 %)	122 ↓ 140	40 ↓ ? < 40 ↓ 45	82 ↓ > 10 (22 %) ↓ 95	—	Slowed and deepened with some periodicity.		+			Extremely low diastolic pressure all time while in hospital. Very young, sent to England to develop.
48. L. D. R.	Pilot. Not flown in France. Concussed 6 months ago, only done light flying since. Feels ill above 5,000 ft.	50′	16,000	96 ↓ 120 (30 %)	140 ↓ 160	68 ↓ 50 ↓ 60	72 ↓ 110 (53 %) ↓ 86		Slowed and deepened, but ventilation moderately increased. Only slight periodicity.	+	+			Showed severe heart [illegible] Good type, but immature. Sent to England. Note pulse pressure.

TABLE G. DREYER'S METHOD—SUBNORMAL CARDIO-VASCULAR RESPONSE

Number and Name.	*History.*	*Duration of Test.*	*Height of Test in Feet.*	*Pulse Rate Change.*	*Systolic Pressure Change.*	*Diastolic Pressure Change.*	*Pulse Pressure Change.*	*Blood Volume Change. (Time in brackets.)*	*Respiration Change.*	Symptoms. *Headache.*	*Sleepiness.*	*Dyspnoea.*	*Syncope.*	*Remarks.*
8. K. W. C.	Pilot. 20 hrs France. Dizziness at any altitude. Landing headaches. Short of breath on ground. Tachycardia.	72′	19,000	97 ↓ 113 (17 %)	134 ↓ 140	76 ↓ 64 ↓ 78	58 ↓ 70 (20 %) ↓ 50	100 ↓ 96 (38′) ↓ 95 (63′) ↓ 101 (80′) ↓ 98 (98′) ↓ 105(118′) ↓ 105(118′)	No record. Some periodic deep breathing.	—	·	·	—	Disability partly temperamental. Permanently unfit for flying.
9. L. R. S.	Observer. 50 hrs. France. Oxygen-want above 12,000 ft. Very sleepy.	65′	19,000	61 ↓ 74 (21 %)	128 ↓ 138 ↓ 130	88 ↓ 80	40 ↓ 58 (45 %) ↓ 50	No change detected.	No record	·	·	+	—	Could hardly be kept awake during test. Failed at simple sum. Recommended night bombers. Did well.
12. C. H. H.	Pilot. 100 hrs. France. Breakdown after Rubella. Oxygen-want at 15,000 ft. Feels very short of breath on ground. Tachycardia.	60′	15,000	96 ↓ 98 ↓ 81	128 ↓ 120 (swinging)	80 ↓ 66 ↓ 84	48 ↓ 60 (25 %) ↓ 36	100 ↓ 109 (22′) ↓ 107 (59′) ↓ 108 (69′) ↓ 114 (82′)	No record	+	+	—	+	Sent to England. Note considerable increase in blood volume, no trace concentration. (See Chart 6.)

22. R. L. B.	Pilot. 20 hrs. France. Oxygen-want at 14,000 ft.	35′	19,000	91 ↓ 112 (23 %)	132 ↓ 138	64 ↓ 58	68 ↓ 80 (17 %)	—	Deepened and slowed. Slight periodicity towards close.	+	+	-	—	—	Some nervous instability. Recommended for night bombers.
27. C. A. B.	Pilot. 123 hrs. France. Oxygen-want at 9,000 ft.	28′	19,000	79 ↓ 84 (6 %)	150 ↓ 146	90 ↓ 85 ↓ 100	60 ↓ 46	—	Deepened and slowed. Some periodicity.	+					To England. Poor irregular pulse.
30. E. R. J.	Pilot. 100 hrs. France. Oxygen-want 'over 6,000 ft.'	47′	16,000	80 ↓ 89 (11 %)	118 ↓ 106	75 ↓ 68	43 ↓ 38	—	Deeper and faster. Some periodicity towards close.	—	+	-			To infantry.
32. A. H. S.	Pilot. 30 hrs. France. Oxygen-want at 15,000 ft.	49′	19,000	74 ↓ 81 (9 %)	118 ↓ 108 ↓ 118	68 ↓ 64 ↓ 68	50 ↓ 44 ↓ 50	—	Deeper and faster. Periodicity towards close.	—	-	—	—		To England. Too immature for service flying at present.
35. A. G. D.	Pilot. 273 hrs. France. Oxygen-want over 10,000 ft.	37′	19,000	64 ↓ 74 ↓ 64 (16 %)	130 ↓ 136	80 ↓ 70 ↓ 78	50 ↓ 62 ↓ 58	—	Extreme deepening and slowing. No periodicity.	—	+	-			Some history of C_2H_2O. To Artillery Squadron. Eventually to infantry.

5.—REPORT ON THE VALUE OF OXYGEN TO AVIATORS AT RELATIVELY LOW ALTITUDES

BY

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A. Introduction.

Early in 1917 various considerations led us, independently, to think that if flying officers were, under certain conditions, supplied with oxygen during flights beneficial results might ensue. These can be briefly summarized as follows:

(*a*) Mitigation of the fatigue always present after long flights.
(*b*) Abolition of staleness from long periods of flying at the Front.
(*c*) Increase of mental alertness.
(*d*) Increase of muscular vigour.
(*e*) Amelioration of symptoms such as giddiness, fainting, &c.

The advantages likely to accrue, if evidence in support could be secured, were obvious, but for the sake of clearness may be noted:

(1) Fewer breakdowns at the Front.
(2) The skilled pilot will be able to use his knowledge to the full.
(3) Air fights should be more successful on account of increased mental and muscular tone.
(4) The return to flying, or its continuance, will be possible by many officers whose symptoms prevent efficient air work.

Before passing to a brief survey of the physiological and other considerations that led to this investigation it should be emphasized that we have not attempted to deal with great altitude flying for two reasons: first, because the general principle that oxygen is absolutely necessary at such heights is now fully accepted: and secondly, because if the case be proved for low altitudes and short flights it is also proved for great altitudes and long flights.

B. Physiological Considerations.

From a physiological point of view it is necessary to consider the effects of flying upon

(*a*) the cardio-respiratory system;
(*b*) the nervous system;
(*c*) the muscular system.

(*a*) *The Effect on the Cardio-Respiratory System.*

With increasing altitude, apart from consideration of temperature and other conditions, there is in the first place a deepening of the respiration in order to secure the oxygen necessary to maintain the bodily functions. This throws extra work upon the muscles of respiration. At the same time the heart quickens, and thus is established the beginning of a 'vicious circle'. For, an increase in the rate of heart beat means an increase in the hours of work done by the heart as shown by the following figures :

Pulse frequency, per minute.	*Ratio of systole to cardiac cycle.*	*Hours of work, per day.*
50	·31	7·5
70	·37	8·9
100	·45	10·8

This increased work entails an increased oxygen consumption, the supply of which is diminishing; thus each factor reacts unfavourably upon the other.

It has been shown experimentally that the usage of oxygen by the heart corresponds to the rate and maximal pressure of the pulse.[1]

All the devices to render the respiration and circulation efficient will therefore be called into play to meet the varying conditions, so that with prolonged strain a breakdown of the respiratory, cardio-motor and vasomotor control mechanisms is to be anticipated. The position of the pilot in the machine is such that but little help can be rendered by the pumping action of muscle movement, and even allowing for the relief given through the respiratory mechanism this is liable to become fatigued, and the circulatory mechanism must in the end suffer.

The possibility, too, of ill effects due to the washing out of carbon dioxide by the increasing depth of breathing must be borne in mind. It is a well established fact that deep breathing in itself gives rise to symptoms of marked discomfort, which frequently approach a sensation of giddiness.

(*b*) *The Effect on the Nervous System.*

In addition to the psychical strain incurred by the judgement displayed in simple straightforward flight there is the added need of quick response to changing atmospheric conditions (bumps); and in war-time flying there is superadded the strain of judgement involved in work to be done.

But this strain is not only cerebral in nature; there is the constant instreaming of impulses

(i) to the cerebellum concerned in the process of equilibration;

(ii) to the medulla oblongata in making the necessary adjustments of the respiratory and circulatory mechanisms;

[1] Barcroft and Dixon, Rohde, and other investigators (see Barcroft's *Respiratory Function of the Blood*, p. 91. Cambridge University Press).

(iii) to the spinal cord for the co-ordination of the reflex movement in the static muscular work involved ;

all this in a rarefied, and frequently in a progressively rarefying, atmosphere.

(*c*) *The Effect on the Muscular System.*

The point of prime consideration in connexion with the muscular system is that with increasing height the muscles are called upon to work with a less and less available supply of oxygen. This results in the progressive formation of lactic acid within the muscles, so that, after a flight, as Zuntz has also pointed out, the muscles of the aviator are in the condition of an athlete after a strenuous piece of work. The work of the aviator varies according as he be pilot or observer. The muscles of the pilot engaged in the direction of the machine are always in a state of semi-tension, owing to the antagonistic action of the muscles engaged in the 'static' work performed. This state is in itself inimical to a good supply of blood, and when the disadvantage of the rarefied atmosphere is added it can be understood that a state of fatigue is easily induced without the need of a large amount of actual work being performed. The observer is usually called upon to do more actual muscular movement, and this brings about a similar state of fatigue in the muscle.

(*d*) *The Summation of Effects.*

It is not suggested that one flight, whatever be its nature, is in itself deleterious, or, except in the case of great altitudes, calls in any way for the administration of oxygen, except to those totally unfitted to fly. But, from what has been written, it will be seen that the strain of flying will tell, soon or late, upon the aviator through the cardio-respiratory, nervous or muscular mechanisms, the degree depending largely upon the individual—thus causing many of the failures in the Field.

C. Experience of Medical Boards.

That the above surmise is true is proved by experience. Medical Boards on flying officers and examination of pilots in the Field have led to the recognition of symptoms and signs, which may now be considered as directly due to prolonged air work at various altitudes. The symptoms are not so definite or simple that anything in the nature of a definite air disease syndrome can yet be claimed for them ; but their appearance and reappearance in overlapping groups is distinctly suggestive.

Thus, in the 'stale' pilot we find definite evidence of either a breakdown in the cardio-respiratory mechanism, or in the nervous or muscular systems.

The cardio-respiratory type is recognized by an increased frequency of the pulse, which is also poor in volume and low in tension ; distress on slight exertion accompanied by a rapid rise in the pulse rate, which returns only after a long interval to its former rate. The breathing also is frequently shallow and rapid, and the extremities poor in colour and cold.

The nervous type demonstrates itself by poor muscular control over balance movements, fine tremors of hands and eyelids, greatly increased reflexes, loss of sleep, nightmares, starts, apprehensions, increasingly bad landings or giddiness in the air.

The muscular type manifests itself chiefly by tender muscles (often erroneously called rheumatism), the tone and power of which are also markedly diminished.

This last type, in its pure state, is only found among the successful pilots, and yields rapidly to rest. It is usually associated in a greater or lesser degree with the cardio-respiratory or nervous type.

This brief and incomplete *résumé* of the signs and symptoms so frequently found in the flying officer is sufficient, however, to show clearly that they correspond closely with the symptoms and signs that, it has been shown, would be expected on physiological grounds.

It is possible that objections to the use of oxygen in excess of that existing in normal atmosphere may be raised, on the grounds that it is 'drugging' and liable to lead to temporary exaltation with subsequent depression, or to an oxygen habit.

Such objections, however, are not in any circumstances valid, and certainly not under those in which it is proposed to use the oxygen. It must be recognized that oxygen is always available under normal conditions in excess of the requirements of the body; and it is only when we make the conditions abnormal, and repeat them day after day for long periods, and, in addition, diminish the available oxygen to a greater or less degree, that an artificial supply of this vital gas may be required.

D. Reasons for the Administration of Oxygen.

It has been shown by one of us, in conjunction with Leonard Hill, that oxygen greatly improves the condition of athletes (runners, hockey players and boxers). If administered *before* a short period of exertion, e.g. 100 yards, it may improve the time of the performance, and certainly alleviates the distress of it; if at intervals *during* a performance, e.g. boxing, it greatly diminishes the distress caused by the previous performance, improves the form for the next round, and increases the staying power of the combatant. If administered *after* a period of long work, e.g. a three-mile race, it decreases the subsequent symptoms of fatigue—the runner will suffer little or no 'stiffness' or other after effects. By the administration of oxygen M. F. was able to restore a delirious cross-channel swimmer to consciousness, brace him to renewed effort, enable him to surpass any previous performance and almost to achieve his end.

Briefly stated it has been shown (Hill and Flack) that the administration of oxygen:

(1) tends to keep an efficient slow pulse;
(2) tends to keep up a good arterial pressure and delay the onset of arterial hypotension (blood pressure below normal);

(3) keeps off the onset of hyperpnoea or dyspnoea (distressful breathing);
(4) mitigates any ill effect due to excessive deep breathing.

In sport the use of oxygen is regarded as a 'dope'. In warfare it is not a question of 'doping' but of 'efficiency'. No athlete could stand a repeated performance of hard muscular work day in day out, often several times daily, without developing 'staleness'. The aviator is in the same position, but has the extra disadvantage of the psychical strain and the performance of his task in a rarefied atmosphere. We suggest that it is not necessary for this atmosphere to be so rare as to produce immediate symptoms, then there can be no denial as to the use of oxygen, but we urge that oxygen, which has been shown to be of the value already mentioned, will from the above considerations be likely to prove useful in preventing many of the symptoms attributable to flying even at relatively low altitudes.

We have made, in support of this contention, some preliminary observations which are given below.

E. Methods of Research.

It was not found possible to carry out observations on pilots flying machines to considerable altitudes for some hours; observations therefore were made chiefly on the B.E. 2e type of machine, making short flights of approximately half an hour at comparatively low altitudes, and flown both by pilots of experience and ones suffering from some disability. If, therefore, the results only show moderate advantage from the use of oxygen it must be remembered that short, low flights in stable machines by pilots of experience are the absolute minimum of flying effort.

The apparatus used for supplying the oxygen was the Siebe Gorman Oxygen Apparatus, similar to that originally despatched to the Expeditionary Force.

The observations taken may be divided up into cardio-respiratory and nervous. It had been intended to make the observations more comprehensive, e.g. by dynamometer tests, vital capacity measurements and alveolar air analysis, but considerations of the daily work and routine of the squadron were held to be more important, and only the smallest possible number of observations were made.

The *cardio-respiratory* observations made before and after each flight were:

(1) Pulse rate (taken twice or three times over half a minute).
(2) The ability to hold the breath (see No. 7 of this volume).
(3) Arterial Pressure, in the majority of cases by means of the small Leonard Hill sphygmomano-meter; the accuracy of the reading being secured by one observer taking the pulse, and the other reading the instrument where any doubt existed.

The *nervous system* tests had to be limited to McDougall's dotting machine, as it had been found impossible to arrange for

wireless signalling or battery work tests on account of the unreliability of results. The McDougall machine, the use of which we owe to the suggestion of Sir Walter Fletcher, F.R.S., consists of a clockwork apparatus which passes a slip of paper through a small opening, and on the slip small circles with a dot in the centre are printed at irregular intervals and positions. The subject endeavours to spot the bull's eye of every circle as the slip of paper passes through the opening. The rate of movement of the paper is gradually increased until a breakdown is secured. The slip is then marked according to the following rules. Ten complete misses out of twenty circles constitute a complete breakdown at the particular rate at which this occurs. The rate immediately preceding this breakdown is then assessed as follows : [1]

> Plus 5 marks for a bull's eye, and minus 1 for a miss (20 circles being counted). The fastest nominal rate is 1, and for this 100 marks are given; for rate 3, 80 marks; rate 5, 60 marks, and so on. Thus, Lt. J. has 11 misses at rate 5 and is considered to have broken down, but at rate 6 he has only 8 misses and has secured four absolutely accurate spots = bull's eyes. His marks, therefore, would be 40 − 8 (misses) = 32 + 20 (4 bull's eyes) = 52.

Psychical.—Note was also taken of expressions of opinion volunteered by pilots, and these appear where they are considered of value in the ' remarks ' column of the data.

In regard to the *muscular system* it was felt that the flights were not of such duration or height as to warrant correct deductions being drawn.

F. Results of Observations.

Table I.

Table showing the effects of a flight upon the Cardio-Respiratory and Nervous Systems without and with the administration of Oxygen.

Name.		*Pulse.*	*B.P.*	*Breath held.* (Secs.)	*McDougall marks.*	*Remarks.*
1. Lt. K.	(1) Before flight.	96/88	120	47/59	29	Flights were 20 minutes, up to 5,550 and down again.
	(2) After flight without oxygen.	108/96	95	34	24	
	(3) After flight with oxygen.	100/86	125	47/55	63	

[1] The following simple method of marking is now used : 2 marks for a bull's eye or completely within the circle, 1 mark if touching outer circle, 0 for a miss. Twenty circles are counted at each speed.

Name		Pulse.	B.P.	Breath held. (Secs.)	McDougall marks.	Remarks.
2. Lt. K.	(1)	84	125	51	45	Flight (2) without oxygen was straight flight for *half* hour. (3) With oxygen approximately same sort of flight for *one* hour.
	(2)	84	95	35, 45	54	
	(3)	84	120	52, 51	47	
3. Lt. S.	(1)	74	105	61, 80	−8	In flight about half hour without oxygen. (2) Half looped, side slipped, &c. Flight (3), with oxygen, 'more strenuous'.
	(2)	96, 84	110	67, 80	32	
	(3)	75, 72	120	90	69	
4. Lt. C.	(1)	79, 84	110	73, 79	98	Both flights approximately the same. Straight up to 3,000 (without), 3,500 (with oxygen), and back.
	(2)	98, 84	120	58	124	
	(3)	96, 84	120/130	86	136	
5. Lt. P.	(1)	84	115	55	24	Both flights to 5,000 with 'stunts', more 'stunts' with oxygen.
	(2)	60	150	52, 57	−4	
	(3)	72	130	61, 68	15	
6. Sgt. C.	(1)	96	120	68	21	Straight climbing to 6,000 and back. Feeling of weirdness without oxygen; no such feeling with oxygen.
	(2)	84, 92	100	50, 77	7	
	(3)	72	125	66, 81	39	
7. Capt. R... ..	(1)	88	110 Retn.	47, 58	2	Straight flights to 3,000 and back. Subject just off sick leave.
	(2)	112/88	90, 130	69, 75	40	
	(3)	96, 92	14	85	61	
8. 2 Lt. H... ..	(1)	80	100	90	106	Contradictory result with oxygen test; arrived down with cylinder empty, and suffering partly from effects thereof.
	(2)	96	120	76	40	
	(3)	84	105	61	(not taken)	
9. 2/Lt. C.	(1)	78	105	95	25	Artillery shoot of just over an hour *without* oxygen.
	(2)	64	95	95	5	
10. 2/Lt. H. ..	(1)	96, 80	130, 120	74, 72	116	Artillery shoot of over an hour, *with* oxygen.
	(3)	74, 72	115, 120	87	148	
11. Capt. F. ..	(1)	72	130	81	92	Flight of 20 min. by experienced pilot, without oxygen. Some 'stunts'.
	(2)	75	150	63	83	
12. Capt. J. ..	(1)	64, 60	—	81, 86	—	Flight of 20 min. by experienced pilot, with some 'stunts'.
	(2)	72, 68	—	62, 70	—	

Name		*Pulse.*	*B.P.*	*Breath held* Secs.	*McDougall marks.*	*Remarks*
13. Lt. F.	(1)	88	—	56	—	Flight, 30 min. by experienced pilot,
	(2)	72	—	58	—	*without* 'stunts'.
14. Lt. F.	(1)	68	—	59	—	Flight by same pilot on another day,
	(2)	104	—	47	—	*with* 'stunts'.
15. 2/Lt. W. S. .. (Pilot)	(1)	92	—	45	—	After strenuous artillery shoot at
	(2)	140	—	25	—	1,500 feet for 30
		116	—	35	—	minutes.
		100	—	41	—	
16. Obs. S. ..	(1)	92	—	35	—	After artillery
	(2)	148	—	32	—	shoots without (2)
		104 after 5 min.	—	44	—	and with (3) oxygen. The oxygen result is compli-
	(3)	120	—	30	—	cated by the fact
		84	—	50	—	that the subject
				60	—	opened the by-pass, emptied his cylinder, and arrived with oxygen exhausted.
17. Obs. Lt. F. ..	(1)	108, 88	—	47, 57	—	An excitable subject on graduated
	(3)	96, 80	—	61, 61	—	flying. Twenty minutes' flight, with 'stunts'; stated next day 'never felt so well after similar flight before'.
18. Obs. Lt. B. ..	(1)	108	—	57, 50	—	Flights to 1,500 and back in 30
	(2)	108, 96	—	32, 50	—	minutes.
	(3)	88, 84	—	55, 62	—	
19. Obs. Lt. R. ..	(1)	108	—	57, 60	—	Flights to 3,000 and back in 40
	(2)	108	—	50, 37	—	min.; after oxygen
	(3)	108	—	55, 80	—	*hurried back some distance for observations.*

Table II.

The effect of Administration of Oxygen after landing from Flight.

Subject.	*On landing.* *Pulse.*	*B.P.*	*Breath held.* (Secs.)	*After one minute's oxygen.* *Pulse.*	*B.P.*	*Breath held.* (Secs.)
E. L. (Observer)	108	—	55	72	—	74
R. McD. ,, ...	80	—	74	72	—	121
B. ,, ...	120	85	18, 20 (after exercise 16)	87	110	24 (after exercise)

Discussion of results.—It is not pretended that these observations on flights at comparatively low altitudes and generally of short duration are altogether conclusive. Certain facts, however, appear to emerge. In regard to the cardio-respiratory system, the results appear to be analogous to those already observed by Hill and Flack as the result of exercise. In general, the pulse is accelerated, the arterial pressure raised, and if the effort be prolonged or cause strain a hypotension supervenes. It is, perhaps, well not to pay too much attention to the pulse rate before a flight owing to the initial excitement, especially in subjects of a nervous temperament. A short flight without oxygen appears to have little effect upon an experienced normal pilot. If he has stunted at all he may have acceleration of the pulse, an increase in arterial pressure, a diminished power to hold the breath, and some nervous exhaustion as shown by the McDougall machine.

To pilots to whom the strain of flying is greater (e.g. Table 1, Nos. 1, 2, 6, 7) there results an arterial hypotension analogous to that of prolonged exercise. The administration of oxygen has a beneficial effect, the subject, even when of an excitable nature, landing with a slow, full pulse, a normal or raised arterial pressure, an increased power to hold the breath.

The abolition of the onset of the hypotension of arterial pressure is of great significance (Table I, Nos. 1, 2, 6, 7).

The results of the observations 9 and 10, Table I, are suggestive; 2/Lt. C. and 2 Lt. H. make approximately the same performance (an artillery shoot of one hour's duration). Lt. C. arrives back with some signs of circulatory and nervous fatigue. Lt. H., although slightly longer in the air, arriving back in good condition with no signs of fatigue, his only complaint being of the smell of the mask used.

The results with the dotting machine indicate an all-round improvement with the administration of oxygen. Of nine cases, six deteriorate after the flight without oxygen and three improve; after the flight with oxygen all make improved performances, and in the cases where there was previously a deterioration surpass the previous performances.

The contradictory results, obtained when the oxygen supply fails, point to the necessity of the employment of a thoroughly well tested and reliable apparatus.

The beneficial results of oxygen administered after a flight are well seen in two of the three instances given in Table 2. Observer B. is a particularly interesting case. After a flight of twenty miles at 1,000 feet he arrived with a rapid pulse, an arterial pressure of 85, and a very limited power to hold the breath (only 16 seconds after the exercise of touching the toes four times). After the administration of oxygen for one minute, the pulse was slower, the blood pressure and power to hold the breath increased. This officer has already fainted in the air three times in six hours' flying experience. Similar results, especially in the improvement of the rate of pulse, have been obtained by the administration of oxygen to pilots home from overseas with cardio-vascular debility after long periods of service.

No observations have been made as to the effect of administration of oxygen after flight upon the performance with the dotting machine. Two instances may be quoted in which the administration of oxygen for one minute to mentally fatigued persons improved the performance 30-40 per cent.—in one case raising the percentage of hits from 65 to 97·5, with the machine going at a medium rate.

G. Discussion as to the best methods of Administration of Oxygen.

The method of continuous administration has been considered best for aviators owing to the fact that the atmosphere is rarefied. It is the method which we have employed in our experiments. The method necessitates the continuous wearing of a mask and requires a relatively large supply of available oxygen. When only limited supplies of oxygen are available we would suggest, however, that there is much to be said for an intermittent supply of oxygen when in the air. Several pilots also have stated that they could not fight with a mask on the face and with a tube in their way. As a pilot of experience said: 'Would it not be better to have a good dose when the Hun was coming, then put it aside and go for him and take another dose when he was finished with.'

When oxygen is not carried for any reason we suggest that it would be a good practice to administer oxygen for a few minutes to all airmen after heavy flights at any altitudes, e. g. bombing raids, &c. We support this contention from the effects obtained by administration to three-mile runners. In our opinion such administration would, as with the long-distance runner, abolish much of the effects of fatigue and appreciably increase the length of service in the field.

H. Conclusions.

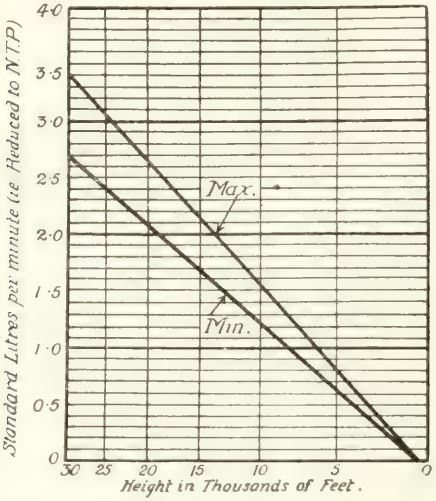
It is provisionally concluded that:

(1) In flights at low altitudes there is a certain degree of cardio-respiratory and nervous fatigue, varying with the nature of the flight and with the individual;
(2) The administration of oxygen abolishes this fatigue in short flights, and delays its onset in longer flights;
(3) The administration of oxygen after a flight improves the cardio-respiratory condition of the subject.

Addendum.

After the date of the first circulation of this report, oxygen was used overseas in increasing amount on high-flying machines. It was supplied from light cylinders carried beneath the lower planes, its delivery being regulated by an apparatus designed by Professor Dreyer (Dreyer Apparatus Mark I or Mark II). Administration was continuous by means of tubing and a special mask. The results

were satisfactory, the following graph showing the amount of oxygen given at various altitudes.



6. THE SELECTION OF CANDIDATES FOR FLYING

REPORT ON THE EXAMINATION OF A SERIES OF SUCCESSFUL PILOTS AND UNSUCCESSFUL PUPILS FROM THE POINT OF VIEW OF THEIR CARDIO-VASCULAR AND NEURO-MUSCULAR SYSTEMS

BY

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A. INTRODUCTION.

THE object of this examination was in part to see what type of subject, if any, makes the most efficient pilot, and also in part to ascertain if the standards adopted by the Commissions Board for the admission of pilots were too strict, especially from the point of view of cardio-vascular and nervous debility.

At the same time it was hoped that the examination would yield information as to the degree of importance of some of the tests employed by the Commissions Board.

The routine procedure of the examination was as follows:

(*a*) Age.

(*b*) *Flying History.* Details of admission to R.F.C., number of hours' flying, average height, maximum height.

(*c*) *Medical History.* History of concussion, faints, serious illnesses, chilblains, &c.

(*d*) Pulse conditions at rest, with the arm in the horizontal and in the vertical positions.

(*e*) Systolic and diastolic sphygmomanometer readings of blood pressure, with the arm in horizontal (heart level) and vertical positions.

(*f*) Condition of jugular veins as regards engorgement in the recumbent position, without and with pressure on the abdomen.

(*g*) Condition of abdominal wall as regards firmness, and of stomach as regards splashing.

(*h*) Reflexes, tremors, and equilibration.

(*i*) Effect of exertion (raising the body on a chair 5 times in approximately 15 seconds) on the pulse rate; also the rapidity of return of pulse to the rest rate after such exertion.[1]

[1] No tests for the respiratory system were included, since these were already being investigated. (See 'Tests for Flying Efficiency', &c., No. 7 of this volume.)

B. Material.

Flying officers engaged in various capacities have been examined; these may be grouped as follows:

(*a*) O.C.'s, Flight Commanders, and Instructors of Flying Schools	29
(*b*) Test Pilots	17
(*c*) Home Defence Pilots	30

These may be conveniently grouped into those at present employed on low-flying machines (15) and those on scouts (15).

The opinion of the O.C. was taken as to the capabilities of each officer examined. In addition we examined 17 good pupils and 8 unsuccessful pupils, as chosen by the O.C.

[Later (June 1918) one of us (A. P. B.) examined the records of a series of successful and unsuccessful pupils, particularly from the point of view of the neuro-muscular system (see Section E).]

C. Results.

(*a*) *Age.*

The average ages of the series may be tabulated as follows:

Pilots.	*Years.*
Flying Schools	26·1
Test Pilots	24·7
Home Defence:	
Low Flying	22·1
Scouts	23·8

Observations.—Scrutiny of the capabilities of these pilots has demonstrated that the man of 20–27 years is more likely to make an efficient flying officer than youths of 18–20.

Since flying exposes the human organism to a greater strain than it has probably ever been exposed to before, it appears to us that the subjects should as far as possible be fully grown, so that the whole of the resources of the organism be available to combat the great strain involved. It is hardly to be expected that growing youths can stand up to this strain as well as men of 20–27. For this reason we would suggest, as our observations indicate, that officers and men up to the age of 30 be encouraged to become pilots. From a medical point of view the man of 22–27 is more likely to make good in the air: conversely, many youths of 18 now passed for pilots would really be more efficient in the infantry. By this it is not meant to suggest that no candidates of 18 should be accepted. It is necessary to bear in mind that the cardio-vascular and nervous systems at this age are frequently unstable, owing to immaturity, and that these youthful candidates have often been subjected to little or no nervous stress. How they will meet such stress can only be determined by the test of actual flying. In this test a fairly high percentage are now found wanting, at considerable cost in time and money to the country. For these reasons alone it appears advisable in recruiting for service in the air to draw more generally from a class of men in which some degree of natural selection has been at work, e. g. a period of service in the trenches.

(b) *Flying History.*

Practically all the candidates had been admitted without special medical examination at the Air Board, and therefore represent the survival of the fittest.

The average number of hours flown and the average height of flying of the three classes of pilots is as follows:

	No. of hours flying.	*Average height.*
Flying schools	574·6	8,890
Test pilots	418·4	7,770
Home defence—		
On low-flying machines ..	271·1	8,630
On scout machines ..	362·6	10,730

(c) *Medical History.*

The outstanding feature of the medical history was the number of pilots who had suffered from concussion at some period of their career (approximately 40 per cent.). In some cases it was severe; for example, Lt. E. G., M.C., while in the infantry was buried twice in one day, was unconscious for about half a day, in hospital for three months, with speech affected for three weeks. Since admission to the R.F.C. he has done eight months flying in France, is now engaged in Home Defence night flying, feels fit, and is described by his O.C. as a good steady pilot.

Other pilots gave a history of periods of unconsciousness up to seven days. One pilot who had sustained a fractured base, and various other injuries, and was unconscious five days, is now doing useful work as instructor. It would appear that in the absence of any signs of nervous instability, except in recent cases, a history of concussion or unconsciousness due to head injury is a point in the subject's favour as showing the ability to withstand these shocks to the nervous system, perhaps also as indicating in many cases the enthusiasm and recklessness characteristic of the flying temperament.

A certain number of subjects examined had suffered from bad headaches in childhood, but had experienced no recurrence since flying.

The fact that some pilots experienced considerable headache when flying at high altitudes, but not when flying at lower altitudes, e. g. on artillery observation, emphasizes the fact that it would be well if pilots could be graded for the type of work for which they are most suitable. A pilot, for example, who suffers from headaches at altitudes is more likely to perform a lengthy period of good work at 8,000 than at 15,000 feet.

(d) *Physique.*

Practically all the subjects were of good physique. It cannot be said that any type of physique is especially characteristic of the flying man. There were examined the sturdy stock type, the tall lean type, &c.

It would appear from this series that a good physique is of the greatest importance, especially in the high flyer.

Physique, however, is not the whole story, since flying is essentially a question of temperament.

It must be confessed that in our opinion the 'flying temperament' largely baffles assessment at present. Thus we examined a pupil who, from the medical point of view, should have made an efficient flying officer. We learnt that he had practically to be driven into the machine. We also met several other cases of officers who exhibited marked disinclination to fly, but in whom no apparent medical symptoms were manifest to account for this.

(e) *Circulatory System.*

Pulse rate.—The pulse rate at rest and after exercise, together with the time taken to return to rest rate, is given in the following table:

	Pulse rate at rest.	*Pulse rate after exercise.*	*Increase.*	*Time taken to return to rest rate.* (Secs.)
Flying school	87	114	27	20
Test pilots	84	109	25	25
Home defence—				
Low	101	126	25	16
High	85	110	25	18

Blood pressure.—The average systolic and diastolic pressures in the series are given below. These were taken with the arm at heart level and also with the arm raised through an angle of 120°. Both the systolic and diastolic pressures were taken by the auscultatory method, the systolic pressure being read preferably at the point of reappearance of the pulse on coming down after previous obliteration by the armlet pressure).

	Arm at heart level.			*Arm raised through an angle of 120°.*		
	Systolic pressure.	*Diastolic pressure.*	*Pulse pressure.*	*Systolic pressure.*	*Diastolic pressure.*	*Pulse pressure.*
Flying school ..	120·6	89·3	31·3	100·2	70·2	30·0
Test pilots ..	121·4	82·8	38·6	103·2	63·5	39·7
Home defence—						
Low	119·1	77·7	41·4	98·5	58·0	40·5
High	122·5	74·9	47·6	102·9	52·6	50·3

Observations.—From a consideration of our observations on the cardio-vascular system it is possible to draw the following conclusions:

(*a*) That the observation of increase of pulse rate after exercise, and the time it takes to return to the rest rate, is a useful method of testing the functional efficiency of the cardio-vascular system. With the method of exercise adopted by us an increased rate of over 25 and a return period of over 30 seconds are points calling for careful consideration of the candidate's cardio-vascular system. It is to be observed that a rest rate above normal, especially if influenced by respiration, is not regarded as necessarily throwing doubt upon the functional efficiency of the cardio-vascular system. A pulse of 60 to 72 little raised by exercise (10 beats per minute), returning to

normal in 10 seconds, is in our opinion a good sign, generally associated with excellent physique and good stability of the nervous system.

(*b*) From a consideration of the blood pressure records, the conclusion is forced upon us that stress of service or high flying almost invariably produces a low diastolic pressure and a big pulse pressure, due probably to lessening of vaso-constrictor tone of the arterioles.

A diastolic pressure below 70 mm. Hg. combined with a pulse pressure greater than 50 mm. Hg. is strong evidence that a cardio-vascular system is unsuited for air work. In showing how this rule would have worked out in actual practice among the various groups examined, the following table will be of value:

	No. examined.	*No. of P.P. over 50.*	*% P.P. over 50.*	*No. of D.P. below 70.*	*% D.P. below 70.*	*No. of cases with P.P. 50+ and D.P. 70 —.*	*% with P.P. 50+ and D.P. 70 —.*
Flying school instructors ..	29	0	0	0	0	0	0
Test pilots ..	17	4	23·4	3	17·6	2	11·7
Home defence —							
Low	15	3	20·0	1	6·6	1	6·6
Scout	15	6	40·0	3	20·0	3 [1]	20·0
Pupils under instruction							
Successful ..	17	4	23·4	5	29·4	0	0
Failures.. ..	8	5	62·5	4	50·0	4	50·0

It should be borne in mind that in the case of test pilots recent nerve strain was common, and in the Home Defence Squadrons the pilots were being subjected to fairly constant stress, and there is every reason to believe that with a period of rest these would conform to the requisite standard. The instructors at flying schools and the successful pupils satisfied this test without exception, while four of the eight unsuccessful pupils would have been rejected on the score of cardio-vascular deficiency. The other unsuccessful pupils, it should be observed, were of the nature of the 'temperamentally unfit'. It is not suggested that this test should be applied rigidly without consideration of other points in the candidate's condition.

Indeed, in all subjects failing in this test, and particularly borderline cases, the other points (soft abdominal wall, splashing stomach, engorged jugular veins, reflexes (brisk or exaggerated), tremors, poor balance, local signs) should receive due consideration. In this series it was found that failure to comply with this blood pressure test was almost invariably associated with two or more of these abnormal physical signs. Indeed, all these signs are presented by the advanced cardio-vascular defective.

The ideal pulse for a flying officer has a small range between systolic and diastolic pressures (20–30), with a rest rate increased

[1] One of these has since been killed; he was passed by the Commissions Board as observer only, unfit as pilot. Another has been taken off flying for a time (Jan. 1918).

at most 20-25 by exercise and returning to the rest rate in 10-15 seconds.

Engorgement of jugular veins.—In regard to the condition of the jugular veins, sixteen pilots exhibited slight engorgement. It is thought that engorgement of the jugular veins, with the subject in the recumbent posture, points to a heightened venous pressure due to lax arterioles. When pressure on the abdominal wall greatly increases the engorgement, it is looked upon as a sign of ' splanchnic pooling '. This engorgement of jugular veins is almost invariably to be found in severe cardio-vascular deficiency. In those of the series in which it was observed the condition was marked in one case only, an advanced cardio-vascular and nervous defective, still under instruction, who had been categorized by the O.C. as unfit for flying.

Local signs of deficient circulation.—Chilblains and blue hands were met with in seven cases among the pilots examined. In regard to signs of deficient circulation, one point is perhaps worthy of comment. It was ascertained that pilots, whose duty it was to take the air at any moment, frequently had to ascend to great heights in boots and puttees, since these cannot be quickly discarded. Several pilots stated that when flying in boots and puttees they suffered from numb feet, although they did not so suffer when otherwise clad. This statement may of course be somewhat prejudiced owing to the pilot's predilection for shoes and stockings, but, from a medical point of view, puttees are an exceedingly undesirable form of leg wear for any pilot in the air, owing to the fact that the limb volume may be greatly restricted, and the effective circulation of blood thereby hampered.

(*f*) *Muscular Tone.*

Condition of abdominal wall.—The condition of the wall, as judged by palpation, was found to be variable. It was graded as firm, fair, or soft, as follows :

	Firm.	*Fair.*	*Soft.*
Flying school	10	7	12
Test pilots	10	4	3
Home defence—			
Low	11	9	5
Scout	3	6	6

Stomach splash.—This was observed in eleven subjects.

Observations.—The condition of the abdominal wall as regards firmness, and of the stomach as regards absence or presence of splash, affords some information as to the general muscular tone. It is noticeable that the tone of the abdominal wall was less satisfactory among trained pilots than among successful pupils under instruction (see Section D). This indicates that one of the first signs of flying stress is to be found in the loss of tone of the abdominal muscles. This was confirmed later by a special test with a U tube manometer (see ' Tests for Flying Efficiency ' in this volume). A soft ' doughy ' abdominal wall, with a splashing stomach, in addition to denoting lack of tone by allowing the abdominal pressure to fall, aggravates any tendency to splanchnic flooding. Taken in conjunc-

tion with the condition of the other systems, the presence of a soft abdominal wall and splashing stomach is to be viewed with suspicion.

(g) *Nervous System.*

Reflexes.—These were tested especially as regards knee jerks, and in most cases as regards also supinator and triceps jerks. The results of the knee-jerk test were graded as 'sluggish', 'normal', 'brisk', and 'exaggerated', and may be summarized as follows:

	Sluggish.	*Normal.*	*Brisk.*	*Exaggerated.*
Flying school	4	11	13	1
Test pilots .. .	5	1	11	0
Home defence—				
Low	5	5	5	0
High	5	3	6	1

Tremors.—The chief test employed was to examine the fingers, semi-flexed and separated, with the eyes shut and the arms outstretched in front of the subject. The condition of the eyelids, when the eyes were shut, was also generally observed. The degree of tremor was graded as 'absent', 'slight', or 'marked'.

	Absent.	*Slight.*	*Marked*
Flying school	14	9	4
Test pilots	11	6	0
Home defence—			
Low	9	6	0
High	12	2	1

Observations.—Brisk reflexes were not uncommonly met with in pilots doing good work. The knee jerks were markedly exaggerated in three cases: one an instructor who had recently done considerable high flying in France, one a scout Home Defence pilot, a fine stunter, who was suffering from a bad cold and feeling unfit, and one an unsuccessful pilot under instruction presenting signs of considerable cardio-vascular debility and nervous instability. In regard to tremors, these are absent or slight in the good pilot. Those present in the officers of the flying school might be attributed in two cases to periods of strenuous service overseas from which they had just returned; the two others were possibly associated with excessive smoking. This series demonstrates the test as a valuable one, an exaggerated tremor being undoubtedly a disqualification for flying.

As regards equilibration, five successful pilots and three unsuccessful pupils exhibited poor equilibration. Four of the former were high flying scouts, one of whom had a cold and did not feel fit. Slight sway was observed in a small proportion of all groups. The balance of the great majority was excellent. We find therefore that a high standard of equilibration is to be required in pilot candidates.

The exact significance of a slight degree of 'neuro-muscular instability' baffles assessment at present. Thus a subject exhibiting a certain degree of nervous instability turns out in one case to be an excellent 'stunt' pilot, in another case to be useless.

From the point of view of stress on the nervous system we make the following suggestions in regard to the training of pupils under instruction. It appears to us that the practice of testing the

'nerves' of a pupil by 'stunt' performances during his first instruction flights casts an unnecessary strain upon the nervous system. It is possible that the disinclination to fly which sometimes develops during training may be ascribed to such performances. Also in regard to the first solo flight it is better practice, as we understand is often done by instructors, to take the pupil for a preliminary trip, and, if this be satisfactory, to allow him, in the enthusiasm of the moment, to venture out on his first solo rather than to inform him overnight of the intended solo, which he then may anxiously await in a state of nervous trepidation. We would point out also that it would be well if only pilots in whom there is no suspicion of nervous instability be employed as instructors, otherwise they tend to affect the 'nerves' of the instructed, or to instruct inefficiently. It is not fair to the pupil that his instructor should be a pilot suffering from 'nerves' in any way.

D. Observations in Pilots under Instruction.

Although reference has been made, from time to time, as to the results obtained from pupils under instruction, the chief points observed are given in detail here. In addition to the successful pilots, twenty-five pupils under instruction were examined. The same observations were made as in the first series. After the examination was completed, the O.C. divided the pupils into those who were promising to make good pilots and those who were failures.

The result of the examination of these, as regards pulse rate (rest after exercise and return), blood pressure (systolic, diastolic pulse), is summarized below:

	Rest rate per min.	*Rate after exercise.*	*Time to return in secs.*	*Systolic pressure in mm. Hg.*	*Diastolic pressure in mm. Hg.*	*Pulse pressure.*	*Systolic pressure (arm raised).*	*Diastolic pressure (arm raised).*	*Pulse pressure*
Successful	85	109	21	115·7	74·1	41·6	97·1	53·8	43·2
Failures	85	121	23	122·1	68·4	53·7	103·7	51·1	52·6

The result of the examination for the other points observed is as follows:

	Abdominal wall.			*Stomach splash.*	*Jugular veins.*	*Reflexes.*			*Tremor.*			*Equib.*			*Local sigps.*	*Concussion.*
	Firm.	*Fair.*	*Soft.*			*S.*	*N.*	*B*	*Ex.*	*Ab.*	*Sl.*	*Mk.*	*G.*	*M.*	*P.*		
Successful (17)	14	3	0	2	4	3	6	8	0	9	7	1	13	4	0	1	5
Failures (8)	2	4	2	2	1[1]	1	3	3	1	1	3	4	2	3	3	3	4

Note.—*S.* = Sluggish. *N.* = Normal. *B.* = Brisk. *Ex.* = Exaggerated. *Ab.* = Absent. *Sl.* = Slight. *Mk.* = Marked. *G.* = Good. *M.* = Moderate. *P.* = Poor

[1] Much engorged.

In our opinion all the successful pupils would have been admitted. In regard to the unsuccessful pupils, a number would have failed, but what may be termed the 'temperamentally unfit' would probably have been passed at the time when this investigation was made.

E. Analysis of Records of Successful and Unsuccessful Pilots and Pupils.

To amplify the small number of observations made above, one of us (A.P.B.) analysed the records of a series of candidates especially from the point of view of the association of signs of neuro-muscular instability with failure to train as a pilot.

With the exception of the records of Group II, which have already been dealt with, the observations were obtained either from the original medical examination sheet or from medical reports made subsequently at the Invaliding Board. A pupil has been considered successful if he has completed his training and obtained his wings; an unsuccessful pupil for the purpose of this report is one who has been declared by the Invaliding Board permanently unfit for air work, or who has crashed fatally.

The cases whose records have been investigated and compared are included in four groups:

Group I. 1,000 accepted candidates who ultimately became successful pilots. Records taken from original medical examination form, on admission.

Group II. 93 successful pilots and pupils. Of these 76 had qualified and had considerable flying experience, and 17 were successful pupils about to obtain their wings. Records taken on aerodromes.

Group III. 200 accepted candidates who eventually failed to qualify or crashed during training with fatal results. Records taken on admission.

Group IV. 40 pupils under instruction who failed in their training, and were declared permanently unfit by the Invaliding Board. Crashes are not included in this group. Records taken by the Invaliding Board.

The following tests were applied to determine respectively the condition in regard to equilibration, tremor, and reflexes:

(i) Standing for fifteen seconds on one foot with the eyes closed, hands to sides; the raised leg flexed at knee, with foot behind. Only cases showing marked unsteadiness or inability in several attempts to accomplish this test were noted.

(ii) Standing with hands outstretched, fingers separated and slightly flexed. Cases of pronounced tremor only were noted.

(iii) Raising a board on which a tuning-fork was balanced from a table to the level of the shoulder, with the arm extended, and lowering the board to the table again without upsetting the fork.

(iv) Knee jerk. Only cases were noted in which the reflex was definitely exaggerated, mere briskness of the response was disregarded.

The table below shows the percentage of the cases examined which have unfavourable reactions to one or more of the tests.

	Group I.	*Group II.*	*Group III.*	*Group IV.*
	1,000 Successes Records on Admission. Per cent.	*93 Successes Records after Training. Per cent.*	*200 Failures Records on Admission. Per cent.*	*40 Failures Records Invaliding Board. Per cent.*
Poor equilibration alone	1·6	5·3	8·0	5·0
Marked tremor alone	2·0	6·4	5·0	20·0
Exaggerated reflexes alone	3·9	2·1	2·4	2·5
Combination of two of the signs above mentioned	0·5	0·0	3·0	40·0
Combination of three of the signs above mentioned	0·1	0·0	1·0	17·5
Total percentage presenting signs	8·1	13·8	19·4	85·0

It is shown by this table—

(I) That the percentage of cases which gave a bad reaction to the tests are very much greater among the failures —prospective or actual—than among the successes.

(II) That these signs of instability are more obvious in men who have actually flown, whether they have graduated successfully or have failed, and that therefore they may be regarded as signs of the result of 'strain' of flying. The results in Group II are worse than in Group I, and similarly those in Group IV are much worse than those in Group III.

(III) A comparison of the percentages presenting the various signs or combinations of signs in Groups I and III would appear to show that the presence of poor equilibration or marked tremor seriously diminish a candidate's chances of gaining his wings. Indeed, it is probable that 'fair' equilibration and a moderate degree of tremor are indicative of likely failure to qualify as pilot. Exaggerated reflexes, on the other hand, appear to be unassociated with any abnormal tendency to failure. Candidates who present these pronounced signs in combination are so rarely found to be fit in other respects that the number accepted is extremely small. Such figures as are available are, however, highly suggestive of the inadvisability of ever accepting these candidates. This view receives additional support from a consideration of the figures in Group IV, which show the condition as regards these points of 40 unsuccessful pupils on their appearance before the Invaliding Board after failure had occurred.

It is interesting to note that exaggerated reflexes and pronounced tremor occurred in 22·5 per cent. of these cases, exaggerated reflexes and poor equilibration in 2·5 per cent., pronounced tremor and poor equilibration in 15 per cent., and all three signs in 17·5 per cent.

F. Conclusions.

In regard to the standards of the Commissions Board, it may be taken that the would-be pilot is subject to a certain amount of strain by the medical examination to which he is subjected, and that due allowance should be made for this. But it is to be remembered that the strain of this examination is by no means so great as that to which he will be subjected, first, when he begins his solo flying, and later, when called upon to engage in combatant service in the air.

At such times the cardio-vascular and nervous system are subjected to enormous strain and breakdown is of comparatively frequent occurrence. It is of the highest importance, therefore, that no subject with signs of cardio-vascular or nervous instability be admitted at the preliminary examination, the chances being that such a subject will in all likelihood break down during the first period of stress, the stress of training, or if not, will be rendered in such a state that collapse under stress of service is almost inevitable.

It is imperative that the standard adopted allow a considerable margin (1) for the coming stress of training, and (2) for the prospective stress of service.

In regard to the selection of candidates for flying it may be concluded :

(I) That the pulse rate should not be unduly increased by exercise and should quickly return to normal. To ensure this the test here employed (lifting and lowering the body weight to and from a chair 5 times in 15 seconds) is of value, being capable of quick application and affording satisfactory results.

(II) The measurement of the systolic and diastolic pressures is important. A diastolic pressure below 70 mm. Hg. combined with a pulse pressure greater than 50 mm. Hg. is strong evidence that a cardio-vascular system is unsuitable for air work.

(III) A firm toned abdominal wall is necessary in a candidate. Lack of tone of the abdominal muscles is one of the first signs of flying stress.

(IV) As regards the neuro-muscular system it may be concluded that

(*a*) Exaggerated reflexes alone appear to have no prognostic value, and their presence may be disregarded ;

(*b*) Marked tremor and poor equilibration may be taken as signs of poor neuro-muscular stability. The case of a candidate who shows one of these signs only should receive very careful consideration. It is justifiable

to assume that his chances of making a successful pilot are much less than normal;

(*c*) A candidate who shows both marked tremor and poor equilibration is probably unfitted for air work and should be rejected forthwith, unless his condition can be ascribed to some temporary indisposition. The chances are not in favour of his being able to train successfully, and even if this were accomplished, his career as a useful pilot would probably be very short. Under such circumstances the expense to the country, the danger to life involved, and the waste of time to instructors are considerations that render the acceptance of such a candidate unjustifiable.

7.—TESTS FOR FLYING EFFICIENCY AND FLYING STRAIN[1]

BY

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A. INTRODUCTION.

MODERN flying, by its complex and nerve-trying evolutions in a rarefied atmosphere, imposes a great strain upon the aviator, especially at high altitudes. In consequence breakdown is frequent, the patients being found to suffer from gradual loss of power to fly high, associated in addition to frequent psychological manifestations in varying degrees with particular symptoms of cardiac and nervous derangement, like those of quickened pulse rate, increased pulse pressure, splashing stomach, nervous tremor of fingers and eyelids, or poor power of balance.

It is therefore a point of the greatest medical importance that some simple test or tests should be devised by which an aviator, in the incipient stages of breakdown, can be singled out so that the condition may be checked and remedied. It is believed that the simple tests described below, taken in conjunction with other points in the clinical examination, will serve *(a)* to aid in the efficient selection of candidates for flying service, and *(b)* to demonstrate in serving officers the need for rest, or at least for lessened work, at a stage when the pilot himself frequently does not feel justified in complaining for fear of being regarded as a shirker.

Various considerations led the writer to the conclusion that the first breakdown in the bodily systems is probably in connexion with the respiratory mechanism, which, becoming defective in working, reacts, owing to the 'anoxaemia' induced by inefficient respiratory ventilation, upon the cardio-vascular and nervous systems, thereby bringing out secondary signs of cardio-vascular and nervous debility.

Such a view is quite reasonable when it is remembered that it is on the respiratory system that the strain first falls in rarefied atmospheres.

In the first place, by the correlation of simple with more elaborate methods, an attempt was made in April 1917 to devise tests which might exclude from the flying services candidates who were likely to suffer from discomfort in the air, headache, giddiness, fainting, dizziness, nausea, vomiting, pressure in the head, blood rushing to the temples, palpitation of the heart, &c., symptoms which might be due to lack of proper oxygenation of the blood and were likely to render them unfit as flying officers.

[1] This report represents a combination of Report No. 1 (I) and Report No. 3 originally published. Report No. 1 was first circulated type-written in July 1917 and printed February 1918; Report No. 3 was first printed April 1918.

B. Methods of Research.

From a number of pilots a sample of blood was taken, the haemoglobin content, the corpuscular count, and the total oxygen capacity after submission to rarefied atmosphere, determined.

The first two points were barren of results; of the third it is not fair to speak, since the conditions under which the work was done were not suitable for so delicate a technique, and for this reason this method of research was discarded after about ten examinations. The research then proceeded by the taking of

(*a*) the tidal air;
(*b*) the vital capacity;
(*c*) the composition of the alveolar air after full expiration and full inspiration;
(*d*) the composition of the alveolar air after full expiration and inspiration and holding the breath as long as possible, the length of time being noted;
(*e*) by getting the subject to breathe in and out of a bag (described earlier), the carbon dioxide being absorbed by a cartridge containing coke coated with caustic soda.

It is not proposed to give here the results of all the analyses of the alveolar airs. The oxygen content of the alveolar air after holding the breath gave an idea of the amount of diminution of oxygen which can take place in the alveoli before discomfort is induced. This was found to vary from 13·5 to 10 per cent. according to the individual. The idea underlying the test of holding the breath is that, during the holding of the breath, the oxygen content of the air in the lung becomes less and less, so that the subject is, so to speak, at the time ascending to a rarer atmosphere and therefore the degree of rarefaction which can be tolerated without discomfort gives an indication of the height to which an individual can ascend without discomfort. It was argued that a man who can hold his breath long, until the alveolar oxygen content is low, should make a good altitude flyer; a man who can hold his breath but a short time should make but a poor high flyer, or a flyer with poor resolution. This test therefore has been carefully correlated with the bag experiment already described, to which the objections as to the accumulation of carbon dioxide and the embarrassment of the circulation do not apply.

From the point of view of simple tests, therefore, attention was in the first place directed to the vital capacity, and the power to hold the breath after full expiration and inspiration.

As a preliminary measure, figures were obtained in the summer of 1917 from 40 normally successful pilots who were admitted to the flying services without any special medical examination. They were officers of great experience and with three exceptions had flown for 200 hours or more. Furthermore, the pilots in question were selected for examination by the executive authorities, on account of the merit of their flying services. As the result of these preliminary observations, it was found that the minimum vital capacity of any successful pilot was 3,400 c.c. and the minimum time for holding

the breath 46 seconds, this in the case of a 'stale' pilot direct from hard work overseas. The average vital capacity was approximately 3,950 c.c.[1] and the average time for holding the breath a fraction over 66 seconds. In every case what might be termed a normal answer, such as 'I wanted more breath', 'I felt like bursting', was stated as the reason for giving up holding the breath. In marked contrast were the results obtained from a number of officers exhibiting symptoms possibly attributable to lack of oxygen early in their career. A number of results are set out in Table I.

It will be seen at a glance that all the above failed to reach the standard achieved by the successful flying officer.

The remarks of the officer after holding the breath are recorded in the column for the purpose and afford a good idea of what may be deemed an 'abnormal' answer. In many cases the act of holding the breath reproduced the symptoms from which they suffered in the air. In view of their short flying experience, it appears probable that these officers would have been eliminated at their entrance medical examination on the tests which they now failed to pass.

On the basis of these results, it was therefore suggested in July 1917 that the following standards be provisionally adopted by the Commissions Board:

(1) Rejection of all candidates with vital capacity below 3,000 c.c.

(2) Rejection for high flying of all candidates who have a vital capacity below 3,400 c.c. and who hold their breath below 45 seconds (in three times), and *give an answer indicative of 'oxygen want'*.

(3) Rejection or deferring of candidates who have a larger vital capacity (over 3,400) but only hold breath 45 seconds or under.

Owing to the difficulty of obtaining suitable meters, the vital capacity measurement was not used to any great extent; but the breath-holding test was adopted for routine purposes. The results have undoubtedly been beneficial since during the past two years it has become progressively rarer for officers to complain of untoward symptoms during their first few hours in the air.[2]

A valuable variant of the breath-holding test was found to be that of holding the breath after regulated exercise, e. g. raising the body 5 times on a chair in 15 seconds.

[1] According to the calculations of Professor Dreyer this figure indicates a certain amount of fatigue (about 10 per cent.) due to stress of service. [See *Lancet*, Aug. 9, 1919, p. 227.]

[2] Lieut.-Colonel Bowdler, O.B.E., has supplied me with the following figures showing the percentage of pilots of various breath-holding capacities breaking down within one year of acceptance by the Aviation Candidates Medical Board. No results of crashes are included in these figures.

Breath-holding time in seconds.	*Number of Pilots.*	*Permanently or Temporarily unfit for long periods during first year.*	
		No.	*Per cent.*
40–50	131	17	13·0
51–60	273	28	10·2
61–70	208	16	7·7
Over 70	263	18	6·8

TABLE I

Name.	*Vital capacity in c.c.*	*Time breath held.* (secs.)	*Remarks after holding breath.*	*No. of hours flying.*	*Max. height in ft.*	*Average height in ft.*	*Remarks.*
2/Lt. E.	2,100 (Max. 2,400)	25	Made him fuzzy.	10½ (dual)	6,000	1,000	Giddiness and blurring of vision when flying at 6,000. Bag method broke down at 6,000 ft.
2 Lt. S.	4,100	42 (Max.)	All out, dashed uncomfortable.	33	9,500	2,000	Nausea above 7,000 ft. (only three times ever above this, very bad at 9,500). Bag experiment, 9,000 ft.
2/Lt. A. L.	4,200	31		4 (as observer)	6,000	2,500	Great difficulty in breathing, and dizziness at 5,000 after four hours' flying.
2 Lt. Bo.	3,800	19	Head inclined to swim.	6 (dual)	6,000 (once)	—	Has fainted three times below 5,000 ft. With bag method nearly fainted at 3,000 ft.
2/Lt. H. W. A. ..	3,750	34	Headache and throb.	16 (solo)	5,000 (as observer) 3,000 (as pilot)	1,000–2,000	Headaches worse after one hour; has had concussion. By bag method, 'oxygen want' at 4,000.
Capt. P. S. M. ..	3,700	36	Little dizzy: warm in head.	30	8,000	2,000	Goes dizzy and sick in air, with bag method. Broke down at 4,000 ft.
2/Lt. D. W. S. ..	3,500	21	Sort of funny.	2 (solo)	—	—	Dizzy every time he went up.
2 Lt. H. G. G. ..	3,700	40	Head bursting, especially at temples.	P.U.I.	—	—	Bad pressure in head, and discomfort, especially about 2,000.
2/Lt. E. A. P. ..	3,400	45	Rather dizzy.	P.U.I.	—	—	Sick and dizzy in air 2,000–3,000 ft. (probably partly nervous).
2/Lt. S. B. M. ..	2,800	30	Felt little giddy.	Just got wings.	5,000		Feels giddy and faint above 5,000. By bag method broke down at 4,500 ft.
2/Lt. J. B.	3,300	21	Little giddy.	8	2,000	-	Giddy above 1,000.

6555	2/Lt. D. K. L. ..	3,000	55	Felt heart.	P.U.I.	8,000	—	Dizzy and headache, 5,000–6,000 ft. By bag method broke down at 5,500 ft.
	2/Lt. E. W. C. ..	3,200	26	Uneasy.	25	12,000 (once as observer)	—	Solo, feels faint, over 2,000 'oxygen want' and 'nerves'. By bag method broke down at 8,500 ft.
	2/Lt. J. P. W. ..	3,100	45	Head seems to swell.	60	10,000 (once as observer)	—	At 6,000 gets less alert, then not all there. With bag method went very dazed and reached 12,000.
	2/Lt. V. P. J. ..	2,700	15	Blood rushing to temples visible.	P.U.I.	2,000	—	Gets headache and blood rushing to temples at 2,000. Was stood off flying, now P.U.P.
	2/Lt. G. W.	3,200	20	Pressure in head and temples.	Just got wings.	8,000	—	Above 5,000 6,000 ft. pressure in head and temples; blurring of vision. With bag method broke down at 5,000 ft.
6	2/Lt. G. N. ..	3,200	35	Queer in head.	P.U.I.	—	—	Giddy during first flight; with bag broke down at 4,500 ft.

In normal pilots it was found that the breath is usually held about 10 to 20 seconds less than before, but always more than 30 seconds. On the other hand, subjects who experienced symptoms, possibly attributable to oxygen-want in the air, usually held their breath less than 20 seconds after such exercise.

With further work the importance of an efficient respiratory capacity in the flying officer was indicated by a number of observations made in the examination of a large number of pilots who were stated to be suffering from stress of service after many hours' flying.

To quote a few such observations, it was noticed that :

(1) Pilots suffering from stress of service flying frequently had a vital capacity which was obviously too small for a healthy adult, e. g. 2,500 c.c., but try as he would the subject could never show what might be deemed a normal capacity.

(2) Although in measuring the vital capacity a good meter was used which opposed but a small resistance, a ' fatigued ' subject frequently had to be encouraged to ' blow hard ' ; in many cases, indeed, the effort to do so rendered him for the time being flushed and out of breath. If not cautioned, a normal subject tends to overshoot the measuring capacity of the meter.

(3) In the ' bag ' method for estimating altitudes (already described, p. 14), the subject is asked to blow up a five-litre bag to distension. Subjects suffering from stress were noticed in many cases to experience difficulty or inability to do this.

(4) In pilots suffering from stress the power to hold the breath was decreased below the normal, to 25–40 seconds. Unlike, however, subjects who suffer from ' oxygen want ' early in their career, these in several cases did not give an abnormal answer such as ' I became giddy ', &c., but gave a normal answer.

(5) With the onset of ' fatigue ' the musculature of abdominal wall shows signs of loss of tone (see Flack and Bowdler, p. 86).

The observations recorded above suggested a loss of expiratory force and possibly some ' fatigue ' of the respiratory mechanism generally. Gradually the following tests were devised to elucidate these points :

(1) The subject was asked to blow a column of mercury contained in a simple U tube to as high a point as possible, the degree of expiratory force being measured in millimetres of mercury.

(2) Measurement was made of the time during which a subject can, after full expiration and full inspiration, sustain by blowing, with the breath held and nose clipped, a column of mercury 40 mm. high.

(3) The vital capacity was measured by getting the subject to fill his lungs and expire as deeply as possible through a good make of meter.

(4) The supplemental air was determined by asking the subject to breathe in quietly and out quietly as in normal respiration, and then to blow his reserve of air through the meter.

(5) The complemental air was determined by a reverse process, namely, after a quiet inspiration to suck in as much air as possible through the meter. Owing, however, to the difficulty of cleansing the tubes, &c., the determination of the complemental air was abandoned as unhygienic, since a number of the subjects were suffering from colds. It was found, however, that, unlike the supplemental air, the complemental air was not affected, except possibly in one case of extreme fatigue.

(6) In a number of cases the behaviour of the pulse during the sustaining of 40 mm. of mercury in expiration was observed, and in some cases recorded by the Mackenzie polygraph.

(7) The period of ability to hold the breath after full expiration and full inspiration was noted in all instances.

Generally speaking, therefore, the routine procedure of the examination was to ascertain the following particulars :

(1) Name and rank.
(2) Age.
(3) Number of hours flying.
(4) Maximum height of flying.
(5) Average height of flight.
(6) Time breath held in seconds after full expiration and full inspiration.
(7) Vital capacity.
(8) Supplemental air.
(9) Expiratory force.
(10) Time during which 40 mm. of mercury sustained by blowing with the breath held.
(11) Other notes of flying career and remarks.

Sufficient time was allowed to elapse between the various tests.

C. Notes on Procedure in Applying Tests.

In the course of the examination there emerged certain points to which particular attention should be paid.

Holding the Breath.—In the 'Holding the Breath' test the subject was particularly asked to expire audibly as deeply as possible before filling the chest, and the extent of this expiration was noted. While holding the breath the subject was watched and the degree of suffusion of the face, &c., noticed. Inquiry was also made as to the reason for ceasing, and any abnormal answer recorded. The subject must not be told the significance of the test, nor the time he is expected to hold his breath. On no account may he time himself.

As a result of many examinations it has been found that if the subject states that he has done his utmost, is 'all out', there is little point in asking him to repeat the test. In cases of doubt, however,

a repetition of the test has been made after an interval of several minutes.

Vital Capacity.—In measuring the vital capacity, the subject was asked to fill his chest and blow through the meter. Note was made of the manner in which this was done: for instance, whether he blew vigorously and overshot the capacity of the meter, or whether he seemed to experience some difficulty in blowing, leading to a suffusion of the face and breathlessness.

As a rule, three determinations were made, in which the subject expired gently and steadily. In practice it was generally found that the second or third reading would be the maximum recorded.

Supplemental Air.—In taking the supplemental air *at least* three estimations were made, the subject being warned to inspire and expire as normally as possible before blowing through the meter.

Expiratory Force.—In regard to the test for expiratory force, the subject was asked to blow the column *steadily* up to the maximum height and not to swing it up by the momentum of the mercury. As the result of experience it has been found sufficient to take two readings with the column turned away and one with the candidate looking at the column. In the experiments here recorded, however, the subject looked at the column in the first attempt. It was borne in mind that in certain cases the value of the test might be negatived by the subject not trying his best. In such cases, therefore, after the first effort, during which he can see the height to which he has blown, the scale of the manometer is turned away, and he is asked to repeat the performance. Generally speaking, the two performances tally, but when it is suspected that the subject is not trying, he is told to blow harder because he can do better. In such cases the result may well exceed the previous effort. After a rest the manometer is then turned with the scale towards the subject, and he is again asked to blow as much as possible. The person who is not trying will probably not exceed the original limit, which he saw registered.

By experiments on himself the writer has found that 'triers' and 'non-triers' can be picked out. He has found that, supposing he decides to blow up to 60 mm. Hg when he sees the manometer, he is in a quandary when the manometer is turned away, and cannot then assess 60 mm. with any degree of accuracy.

The blowing power of the cheeks may be ruled out by asking the subject to hold his cheeks with his hand and blow only with his chest and abdominal muscles. Generally speaking, however, the cheeks make little or no difference to the reading.

Sustaining 40 mm. Hg by blowing. 'Fatigue Test.'—In regard to the test of holding up 40 mm. Hg with the breath held, the subject is asked to breathe out as far as possible, and then to fill up the chest before blowing up the mercury. The degree of suffusion of the face and the subsequent breathlessness induced are observed; also inquiry is made as to the sensations experienced before the breaking point is reached. Usually these are identical with those experienced during the test of holding the breath. It is well to have the nose clipped during the test.

When the pulse rate is taken during the test, the normal rate is previously ascertained by counting it in periods of five seconds before

TABLE II

No.	Name and rank.	Age.	No. of hours flying.	Maximum height.	Average height.	Time breath held in secs.	Vital capacity in c.cs.	Supplemental air in c.cs.	Expiratory force in mm. Hg.	Time in secs. of supporting 40 mm. Hg by blowing.	Remarks.
1	Capt. C. B. G. ..	24 8/12	71	12,000	3,000	67	4,900	1,700	100	67	Instructing practically all time.
2	Capt. D.	26	750	14,000	3,000	46	3,500	1,900	100	51	Instructing 7 months. Before that France 18 months.
3	Capt. H.	32	650	15,500	2,000	105	5,020	1,500	180	48	Egypt 11 months. No illness.
4	Lt. W. H. ..	19	200	15,000	2,000	72	5,050	2,100	90	45	Not been overseas.
5	Lt. D.	29	54	10,000	3,000	56	3,200	—	80	47	Not been overseas.
6	Capt. H.	25	400	13,000	4,000	68	4,400	—	140	52	In France 5 months. Instructing.
7	Lt. H.	21	70	11,000	4,000	64	3,850	—	90	53	Wounded in head in Infantry. Gets dim vision after long flying.
8	Lt.-Col. C. F. K	34 3/12	600	19,000	9,000	47	3,700	1,300	110	43	Still flying, 2 years active service, Mediterranean.
9	Fl. S/Lt H.A.H.	18 11/12	60	12,200	4,000	68	3,500	1,100	140	48	Recently qualified as Instructor.
10	Fl. Com. S.H.H.	30 8/12	740	15,000	4,000	75	4,000	1,800	120	60	Practically always instructing.
11	Fl. S. Lt. G.R.H.	25 8/12	60	13,000	3,000	53	3,800	1,500	140	45	Instructing only.
12	Fl. S/Lt. G.R.A.	29 8/12	64	11,000	4,000	83	4,300	1,800	110	62	Instructing only.
13	Fl. Lt. L.M.B. ..	23 3/12	700	16,000	3,000	53	3,800	2,000	85	53	Instructing last 13 months.
14	Capt. L. R. F ..	26	200	10,000	2,000	66	4,000	—	140	52	
15	Lt. D. J. A. ..	30 10/12	70 *o* 85 *p*	14,000	12,000 *o* 3,000 *p*	63	4,600	1,800	130	51	Instructing 3 months, from France to train as pilot.
16	Capt. H. L. ..	23	550	14,500	5,000	63	3,700	1,600	100	54	Artillery pilot from France, May 17, instructing since.
17	Lt. A. W. V. ..	28	170 *o* 90 *p*	14,500	5,000	70	3,300	1,200	160	60	—
18	Maj. R. A. A. ..	24 6/12	500	16,000	6,000	51	4,050	1,700	110	54	Little flying lately.
19	Lt. L. M. T. H.	21 2/12	700	18,000	7,000	88	4,100	1,050	80	50	8 mths. instructing. Developed nerves after 6 weeks on S.E. 5 in France.
20	Lt. J. S. T. ..	22 6/12	140	17,500	8,000	63	4,300	1,700	80	45	Recently passed fit for instructing.
21	Capt. D. C. ..	26	320	15,000	7,000	92	4,500	1,700	110	75	
22	Lt. S. H. W. ..	25	100	22,000	17,500	64	3,800	1,800	80	45	Instructing since October.
				Average ..	..	67	4,062	1,620	112	52	

o = Observer. *p* = Pilot.

TABLE III

No.	Name and rank.	Age.	Actual hours flying.	Maximum height.	Average height.	Time to climb to 15,000 secs.	Vital capacity in c.c.s.	Supplemental air in c.c.s.	Expiratory force in mm. Hg.	Time in secs. of supporting 40 mm. Hg by blowing.	Remarks.
1	Capt. H.	22 10 12	250	23,000	10,000	125	4,600	1,800	85	56	Home Defence 11 months.
2	Lt. R. N. H. ..	27 6 12	330	22,000	10,000	77	3,900	1,400	80	57	Home Defence 4 months. Before that served in France 6 months. Home for rest.
3	2 Lt. J. A. S. ..	22 3 12	38	6,000	1,000	90	4,300	1,600	185	85	Recently started Home Defence.
4	2 Lt. J. L. W. ..	18 7 12	100	16,000	4,000	73	4,300	1,600	125	62	Home Defence only.
5	Capt. G. H. H. ..	25	700	21,000	8,000	68	3,800	1,400	85	40	Home Defence 5 months. Ferrying 7 months. Before that Scout in France 9 months.
6	2 Lt. J. C. ..	19 4 12	350	19,000	10,000	52	4,200	1,800	180	50	Home Defence 5 months. Before that Scout in France 200 hours.
7	2 Lt. R. M. F. ..	19 4 12	350	22,000	10,000	63	3,850	1,600	90	38	Home Defence 4½ months. Before that Scout in France 250 hours. Home for rest.
8	Capt. C. J. Q. B.	24 8 12	500	20,000	10,000	85	3,800	1,400	100	50	Home Defence 8 months. Before that Scout 5 months in France (wounded).
9	2 Lt. W. A. P. ..	20 2 12	250	20,000	15,000	63	3,100	1,000	70	36	Small physique. Home Defence 1 month after 1 month's leave. Before that Scout in France.
10	2 Lt. C. C. B. ..	24 1 12									
11	2 Lt. L. F. L. ..	19 6 12	220	17,000	4,000	92	3,800	1,700	140	57	Home Defence 7 months.
			95	17,500	6,000	70	4,200	1,800	125	53	Home Defence since obtaining wings.
12	Lt. R. G. H. A.	21 1 12	120 *a* 125 *p*	16,000	5,000	85	4,800	1,800	90	68	Home Defence 6 months. Before that light duty in France 6 months. Observer (average 12,000 feet).
13	2 Lt. H. A. E. ..	19 2 12	120	19,000	10,000	70	4,300	1,200	145	59	Home Defence 8 months.
14	Capt. D. J. B. ..	25 2/12	650	18,500	10,000	66	4,500	1,800	140	59	Home Defence 5 months. Instructing 1 month. 9½ months France on Martinsydes (av. ht. 14,000) 250 to 399 hours. No illness.

15	2/Lt. W H. ..	23 11/12	300	16,500	10,000	66	4,100	1,400	100	53	Home Defence 6 months. Had been up 30 ms. morning of examination.
16	2/Lt. D. G. L. ..	19 3/12	80	12,000	2,000	77	3,100	1,200	120	66	Home Defence 5 months. Had been up 20 ms. on morning of examination. Crashed and temporarily concussed 2 months ago.
17	2/Lt. T R. B. ..	20 6 12	36	12,000	2,000	75	3,700	1,300	110	63	Home Defence 7 weeks.
18	2/Lt. F. D. H. ..	27 4/12	45	15,000	2,000	71	4,200	1,900	196	57	Had been up 29 ms. on morning of examination.
19	2/Lt. M.H.G.L.	22 7/12	45	15,000	2,000	64	3,700	1,100	110	42	Had been up 25 ms. on morning of examination.
20	2/Lt. L. F. W...	21 3 12	140 *o* 37 *p*	22,000	15,000	65	3,600	1,300	140	47	In high flying squadron as observer in France.
21	Lt. D. V. A. ..	20 6/12	700	21,000	4,000	72	3,800	1,600	130	44	Had been up 1 hour 'stunting' on morning of examination, 280 hours in France. Came home for rest.
22	Capt. J. S. P. ..	22 5/12	150	16,000	2,000	61	3,500	1,300	120	32	'Shortwinded these days.' Not before taking up flying.
23	Lt. W. H. A. ..	25 11/12	170	17,000	10,000	31	3,300	1,300	80	30	Home Defence 7 months. Egypt 2 months. Dysentery Gallipoli. *M.O. wishes him to stand off flying.* Had been ½ hour on observation morning of examination.
24	Lt. G. W. G. ..	22 7/12	150 *o* 420 *p*	22,000	15,000	62	4,100	1,600	105	38	Whenever possible has been to 16,000 twice daily during past 7 months. 'Says he wants leave.'
		Average				72	3,940	1,490	119	50	

o=Observer. *p*=Pilot.

the test is made: then, starting from the moment the mercury reaches 40, counting it every five seconds during the period through which the mercury is sustained.

D. Normal Standards.

The normal standard for the various tests has been set by the examination of a considerable number of selected fit flying officers. In addition, a number of candidates and United States cadets have been examined.

Table II (p. 101) gives the results obtained on fit squadron commanders, flight commanders, and instructors.

Table III (pp. 102 and 103) gives the results obtained on fit pilots engaged in Home Defence (night flying).

It will be seen that the ability to hold the breath averages from 66 to 72 seconds, about the same as that found in the previous examination of successful pilots, e. g. 66 seconds.

The vital capacity is about the same as that found previously, e. g. 3,900 c.c., and the supplemental air is approximately the normal text-book figure, e. g. 1,500 c.c.

The expiratory force averages 112 to 119 mm. Hg, and the average period of holding the breath while blowing up 40 mm. Hg is 52 seconds approximately.

For the sake of comparison, the figures obtained on 24 cadets taken at random from among those passed as fit by the Candidates Board at Arkwright Road are here given in Table IV:

TABLE IV

No.	*Name.*	*Age.*	*Time breath held in seconds.*	*Vital capacity in c.cs.*	*Supplemental air in c.cs.*	*Expiratory force in mm. Hg.*	*Time in seconds of sustaining 40 mm. Hg by blowing.*
1	C. D. G. H. ..	18	84	3,850	1,800	80	45
2	W. N. M. ..	18	70	2,900	1,100	120	45
3	W. E. P. ..	17 11/12	90	4,000	1,800	110	57
4	H. S. H. ..	17 11/12	88	4,200	1,800	80	59
5	E. R. P. ..	18	70	4,100	1,700	110	44
6	R. R. M. ..	18	62	3,700	1,150	110	51
7	J. S. H. ..	17 11/12	62	4,500	1,800	120	52
8	W. H. B. ..	17 11 12	77	3,600	1,600	100	60
9	W. T. P. ..	19 2/12	57	3,800	1,700	120	49
10	D. R. C. ..	19	61	3,400	1,200	120	51
11	H. B. ..	18 1/12	68	4,200	1,800	80	48
12	F. H. ..	21 10/12	52	3,600	1,600	100	44
13	F. T. ..	18 3/12	58	3,700	1,500	90	50
14	2/Lt. P. D. ..	26 2/12	89	4,200	1,800	100	58
15	2/Lt. V. L. W.	21 11/12	77	4,600	1,600	80	51
16	A. F. P. ..	18 2/12	56	3,600	1,600	120	47
17	S. G. S. ..	18 4/12	69	3,700	1,600	90	55
18	G. C. ..	18 2 12	66	4,200	1,700	100	46
19	H. G. G. ..	22 2/	71	3,700	1,600	90	63
20	D. W. ..	23 4/12	70	3,900	1,600	150	60
21	W. S. S. W. ..	19 8/12	68	3,800	1,600	120	46
22	H. F. J. ..	18 1/12	60	3,600	1,200	160	52
23	D. E. H. ..	18 1/12	55	3,900	1,700	90	47
	Average		69	3,823	1,593	106	51

It will be seen that in expiratory force and the power of sustaining 40 mm. Hg. they are a little below the previous standard shown on Tables II and III.

It must be remembered, however, that this is a random sample, and the standard of physique of recruits is not now so high as formerly.

Of interest also are the results obtained upon seven United States cadets, from among those now in training in England, who have passed the official tests of the United States Medical Service.

It will be seen that the average is again about the same as the standard found in the fit pilots examined.

From the above normal standards it would seem that the average standard of a flying officer should be :

Time of holding breath ..	66 seconds.
Vital capacity	3,800 c.c. (approximately).
Expiratory force	110 mm. Hg.
Time of sustaining 40 mm. Hg by blowing	52 seconds.

In Table VI (p. 107) are given the results obtained upon a number of delivery and test pilots.

It will be seen that in these the average falls below the normal standard. This may be accounted for by the fact that included in the number of subjects examined are some pilots who suffer from disability at high altitudes, and for this reason are now being employed as delivery pilots. This being the case, it would be expected (as is found) that the average results obtained from these pilots would be below normal. It will be seen, however, that the pilots suffering from marked disability were picked out by these tests.

The value of these tests became evident from the examinations conducted at the first three aerodromes visited.

At the first aerodrome all instructors available were examined, and no questions asked before the examination : the details of medical history were taken by the Aerodrome Medical Officer, and not by the writer. An examination of the results then showed that all the fit officers had an average for the expiratory force test of 80 mm. or over, and for the sustaining the mercury test of 45 seconds or over. All the officers below this were either unfit for general service or resting after recent high flying in France.

These results are shown in Table VII (p. 108).

At the second aerodrome the medical officer stated that he had two officers unfit for flying. It was agreed, therefore, that they should be examined with the other pilots to see if they could be picked out by these tests.

The results of the examination of the first eight subjects are given in Table VIII (p. 109).

A scrutiny of the results reveals at once that Nos. 4 and 7 were probably the unfit pilots, which actually was the case. The figures also suggest that No. 4 was less unfit than No. 7, which also was true. No. 2 was a pilot of very small physique, recently home from scout flying in France and in need of a rest.

In reality, these two cases (Nos. 4 and 7) illustrate the relative

TABLE V

No	*Name and rank.*	*Age.*	*No. of hours flying.*	*Maximum height.*	*Average height.*	*Time breath held in secs.*	*Vital capacity in c.cs.*	*Supplemental air in c.cs.*	*Expiratory force in mm. Hg*	*Time in secs. of holding 40 mm. Hg by blowing.*	*Remarks.*
1	Cadet W. C. S...	6/12	7 *d*	3,000	2,000	60	3,400	1,350	160	45	Learning with Home Defence squadron. Passed official U.S. examination.
2	Cadet W. F. H. .	22 10/12	4 *d*	2,000	1,000	60	3,600	1,000	120	46	Ditto.
3	Cadet C. K. ..	26 10/12	8 *d*	2,000	1,000	59	3,600	1,050	105	43	Ditto.
4	Cadet G. R. T...	23 6/12	6¾ *d*	2,000	1,000	67	3,900	1,600	120	60	Ditto.
5	Cadet C. B. I ..	24 4/12	6 *d*	5,000	1,000	79	3,900	1,300	100	69	Ditto.
6	Cadet R. B. B...	21 4/12	31 *s*	12,000	4,000	74	4,400	1,700	100	47	Training with Scout squadron. Been up in morning, examined in afternoon.
7	Cadet L. K. C...	23 6/12	4 *d* 4 *s*	3,000	1,000	65	3,900	1,700	110	65	Training with Scout squadron.
				Average ..	..	66·2	3,814·3	1,386	116·4	53·5	

d *Dual.* *s* *Solo.*

TABLE VI

No.	*Name and rank.*	*Age.*	*No. of hours flying.*	*Maximum height.*	*Average height.*	*Time breath held in secs.*	*Vital capacity in c.cs.*	*Supplemental air in c.cs.*	*Expiratory force in mm. Hg.*	*Time in secs. of holding 40 mm. Hg by blowing.*	*Remarks.*
1	[Lt. E. G. M. ..	28 9/12	450	15,000	6,000	60	2,800	—	100	44	Very small physique, does not like flying high.
2	Lt. T. C.	27	350	18,000	10,000	55	3,800	—	140	43	
3	[Lt. F.A.V.W. ..	22 11/12	350	17,000	8,000	17	3,400	—	160	15	Cannot fly above 3,000 now. Killed since. Machine got out of control.
4	Lt. O. M.	25 3/12	200	16,000	4,000	65	3,600	—	70	40	
5	Lt. J. H. R. S. ..	22 3/12	450	19,000	6,000	78	3,700	—	90	38	
6	Lt. R. M.	25 9/12	300	20,000	12,000	63	4,500	—	90	43	
7	Lt. H. T.	21 1/12	120	16,000	4,000	53	3,000	900	140	47	
8	Lt. J. E. E. ..	20 9/12	700	8,000	3,000	37	3,800	1,100	85	27	Always disability at height. Fainted at 8,000. Ferry piloting 400 hours.
9	2 Lt. W. P. W. .	20	200	17,000	3,000	67	3,900	1,000	105	51	
10	2/Lt. G. S. H. ..	24 11/12	200 *o* 60 *p*	10,000	5,000 *o* 3,000 *p*	74	3,700	1,200	105	51	
				Average ..	..	57	3,620	1,050	108	40	

o = Observer. *p* = Pilot.

TABLE VII

No.	*Name and rank.*	*Age.*	*No. of hours flying.*	*Maximum height.*	*Average height.*	*Time breath held in secs.*	*Vital capacity in c.cs.*	*Supplemental air in c.cs.*	*Expiratory force in mm. Hg.*	*Time in secs. of sustaining 40 mm. Hg by blowing.*	*Remarks.*
1	Capt. H.	25	400	13,000	4,000	68	4,400	—	150	58	Fit.
2	Lt. S.	23	150	15,000	5,000	71	4,100	1,900	100	55	Fit.
3	Lt. H.	21	70	11,000	4,000	64	3,850		90	53	Fit.
4	Capt. D.	26	750	14,000	3,000	46	3,600	1,900	100	51	Fit.
5	Capt. H.	32	650	15,500	2,000	105	5,020	1,500	180	48	Fit.
6	2/Lt. D.	29	54	10,000	3,000	56	3,200	-	80	47	Fit.
7	2/Lt. W.	19	200	15,000	2,000	72	5,050	2,100	90	45	Fit.
8	Lt. C.	24	380	10,000	2,000	45	4,500	1,500	130	38	Unfit G.S. France, 6 months. Artillery, 3 months. R.F.C. shell concussion. Sick while flying in France.
9	Lt. M. C.	26	200	10,000	2,000	46	4,000	1,500	70	35	Unfit G.S. Gallipoli, enteric, dysentery, jaundice.
10	Lt. S...	21	500	18,000	5,000	52	3,700	1,000	80	27	'Flying Tired.' Now gets very tired after flying.
11	2/Lt. P.	31	150	18,000	10,000	50	3,700	700	80	27	Resting after high flying in France.
12	Capt. X.	37	800	12,000	2,000	35	4,300	—	120	26	France, East Africa, malaria (C$_6$H$_5$OH).
13	Capt. C.	24	150	18,000	3,000	65	4,100	1,200	65	25	Gallipoli, dysentery, enteric, jaundice. Unfit G.S.
14	Lt. B .. .	22	300	21 000	8,000	33	3,300	-	60	24	Been flying (av. 20,000). Recently in France on D.H. 4. Home for rest.

TABLE VIII

No.	*Name and rank.*	*Age.*	*No. of hours flying.*	*Maximum height.*	*Average height.*	*Time breath held in secs.*	*Vital capacity in c.cs.*	*Supplemental air in c.cs.*	*Expiratory force in mm. Hg.*	*Time in secs. of sustaining 40 mm. Hg by blowing.*	*Remarks.*
1	Capt. A J.Q.B.	24 8/12	500	20,000	10,000	85	3,800	1,400	100	50	Back from France 1st May 17. Scout Home Defence since. 5 months in France (wounds). Before that 2-seaters.
2	Lt. W. A. P. ..	20 2/12	250	20,000	15,000	63	3,100	1,000	70	36	Small physique. From France Nov. 17 for rest. Had 1 month's leave. Been high-flying since 1st July, 1917.
3	Lt. G. C. B. ..	24 11/12	220	17,000	4,000	92	3,800	1,700	140	57	Home Defence scout since June 17 100 hours; average height 4,000 5,000.
4	Lt. C. S. T. L. ..	21 6/12	125 *o* 200 *s*	22,000	13,000	63	3,550	1,600	125	23	125 hours on flight at 10,000 in France. Left March / 17. Leave Nov. 8. Taken off flying by M.O. on day previous; been crashing and making bad landings.
5	2/Lt. L. F. L. ..	19 6/12	95	17,500 *o*	6,000	70	4,200	1,800	125	53	Scout Home Defence since wings.
6	Lt. R. G. H. A.	21 1/12	120 *o* 125	16,000	5,000	85	4,800	1,800	90	68	Scout Home Defence 6 months. Before that light duties in France, Dec. 15—May 16. 12,000 observing.
7	Lt. E. M. G. ..	26	150 *o* 150	16,500	5,000	37	3,600	750	45	23	Taken off flying; been to Dr. Swan previously. Scout Home Defence since July 17. Before that B E 12. Observing July 15—Jan 16. Been flying Jan 16—April 16. Then under Drs. Swan and Head Feb. 17.
8	Lt. H. A. W. ..	19 2/12	120	19,000	10,000	73	4,300	1,200	145	59	Scout since July / 17. Home Defence since April / 17.

o = Observer. *s* = Solo.

value of the tests, namely, that a flying officer suffering from a degree of stress rendering it undesirable for him to fly, will show this in the first place through the test of sustaining 40 mm. Hg. When the flying stress has become more marked, then it is probable that the ability to hold the breath, the vital capacity, the supplemental air, and the expiratory force will also become diminished. Each of these officers has since been examined, and the results are given elsewhere (Table XIX).

In Table IX (p. 111) are given the results obtained at the third aerodrome, an Acceptance Park.

Scrutiny of the results shows that, judging by the standards of fit subjects, one is able at once to pick out the unfit officer.

Case 6 is particularly interesting. He was examined under the impression that he was a particularly fit and experienced officer. He had been posted to the aerodrome the day before, and reports of his past good work had preceded him. It will be seen that the result of the examination was most unsatisfactory, and on inquiry it was elicited that he had been stopped flying at his last aerodrome one month before on account of stress of service. He expressed himself as still thoroughly 'fed up' with flying; and undoubtedly after 900 hours in the air, with 23 days' leave in three years, he was a good example of flying stress.

With a view to determining the value of the tests as a measure of fatigue, a number of pilots who had returned for rest from active service overseas were examined (Table X, pp. 112 and 113).

All these pilots were deemed sufficiently fit to be posted for flying at home; in fact, all were examined at aerodromes where they were flying. It is seen that on the average, especially as regards expiratory force and 'sustaining mercury', they fall considerably below the normal standard.

From the point of view of fatigue also a number of pilots training on scout machines were examined (Table XI, p. 114).

It will be noticed that the expiratory force and 'sustaining mercury' is below the average. Scrutiny of the table, however, reveals the fact that this is due to a certain extent to the performances of some of the subjects rather than to a low general standard.

In regard to the subjects who did badly, the writer considered that *from the point of view of wear and tear*, they were not likely to do well on scout machines, an opinion which was in every case shared by the officer commanding or the flight commander. *It would seem, therefore, that a routine application of these tests to pilots in training for high flying would indicate the powers of endurance of the subject for the fatigue of high flying.*

This is further brought out by the fact that it has been found that a flight, even in some cases to low altitudes, tells considerably more on some subjects than on others. Thus a very fine scout pilot examined after an hour of most amazing flying satisfied the tests (see No. 21, Table III). On the other hand, it is common to find that a pilot just down after 'stunts' or even from a straight flight is unable to hold his breath 40 seconds or sustain the mercury at 40 mm. Hg more than 25 seconds. The vital capacity is also greatly lessened, being frequently under 3,000 c.c. After resting for half an hour or so he will return to

TABLE IX

No.	Name and rank	Age.	No. of hours flying.	Maximum height.	Average height.	Time breath held in secs.	Vital capacity increase.	Supplemental air increase.	Expiratory force in mm. Hg.	Time in secs. of sustained 40 mm. Hg by blowing.	Remarks.
1	Lt. H. T.	21 1 12	120	16,000	4,000	53	3,000	900	140	47	Wooden leg. Delivery 3 weeks. Before that instructing. Home service.
2	Lt. J. E. E. ..	20 9/12	700	8,000	3,000	37	800	1,100	85	27	Fainted 8,000 after about 60 hours. Always disability at height. No A.B. examination. Ferry piloting since March (400 hours)
3	2/Lt. W.P.T.W.	20	200	17,000	3,000	67	3,900	1,000	105	51	Ferry pilot since July. Average 3,000. Instructing 1 month. France. Scout 4 weeks (shot down), 3 weeks on rest.
4	Lt. R. S. H. ..	23 11/12	200	13,500	2–3,000	91	4,300	1,700	80	42	Off regular flying stood off by O.C.'s instructions. Limited flying only. Overseas 4 months. Art. obs. av. 7,000 [illegible]. Crashed, now some dizziness
5	Lt. G. H.	24 10 12	200 *o*	10,000	5,000 *o*	74	3,700	1,200	105	57	Art. observer in France. Delivery case. Not had any disability.
6	Lt. W. H ..	29 7 12	60 900		3,000 7,000	23	2,600	700	50	20	Delivery for 9 months 1,000 feet average. Testing aeroplanes 18 months 20,000–10,000. *Stopped flying by M.O.'s order at last aerodrome. Now fed up.* 23 crashes leave in 3 years. Gets winded if runs 100 yards.
7	Lt. W. F. W. ..	20 6/12	350	20,000	10,000	40	3,250	1,200	110	37	Limited flying. Back from France (Nov. 1). Scout 80 hours. 20,000 at first but not towards end. Now owner for rest. Practically fainted at 18,000. In 1916 was flying Moranes at average 7,000 quite O.K.

o = Observer

TABLE X

No.	*Name and rank.*	*Age.*	*No. of hours flying.*	*Maximum height.*	*Average height of all flying.*	*Time breath held in secs.*	*Vital capacity in c.cs.*	*Supplemental air in c.cs.*	*Expiratory force in mms. Hg.*	*Time in secs of holding 40 mm. Hg by blowing.*	*Remarks.*
1	Lt. B. McE. ..	26 2/12	230	20,000	8-10,000	47	3,800	1,300	60	45	France 6 months on Spads. Home 3 months. Now instructing.
2	Capt. W. E. Y.	26	300	20,000	10,000	65	5,400	2,100	100	35	France Scout 2 months. Average height 10,000 ft. Back 5 months. Flying all the time since.
3	Capt. R. L. K.	25 8 12	500	23,000	5,000	49	3,400	1,000	70	34	France Scout 6 months. Average 14,000. Before that bombing (average 11,000). Now instructing.
4	Lt. P.	31	150	18,000	10,000	50	3,700	800	80	27	France 9 months, 3 months on Scouts (average 16,000). Now instructing.
5	Lt. B.	22	300	21,000	8,000	33	3,600	—	60	24	France 4 months D.H. 4 (average 19-20,000). Now instructing. Still some nervous tremor.
6	Lt. T. C	27	350	18,000	10,000	55	3,800	—	140	43	France Scout (D.H. 2 and D.H. 5). Average 14,000. Now delivery pilot.
7	Lt. J. H. R. S.	22 3/12	450	19,000	6,000	78	3,700	—	90	38	France Scout 6 months. (D.H. 2 and Nieuport.) Average 14,000. Now delivery pilot.
8	Lt. R. M.	25 9 12	300	20,000	12,000	63	4,500	—	90	43	France 6 months, D.H. 4 and Sopwith Scouts. Back 6 months. Now delivery pilot.
9	Capt. C. D. D. ..	30 6/12	750	15,000	4,000	57	3,500	1,500	120	45	France 6 months Scouts. Average 12-14,000. Back 10 months. Now instructing.
10	Lt. R. M. F. ..	19 11 12	350	22,000	10,000	63	3,850	1,600	90	38	France 250 hours, Sopwith Scout. Last 4½ months Home Defence.
11	Capt. G. H. H	25	700	21,000	8,000	68	3,800	1,400	85	30-40	France 9 months, 340 hours on Scout Since then ferrying 7 months. Home Defence 5 months. No leave on return from France for rest.

12	Capt. J. D. B. ..	25 6/12	650	18,500	10,000	66	4,500	1,800	140	59	France 9½ months Martinsydes. Average 14,000. Since then instructing one month. Home Defence 5 months.
13	2/Lt. W. A. P. ..	20 2/12	250	20,000	15,000	63	3,100	1,000	70	6	Five months Scout France. Back 2 months, 1 month's leave. Now Home Defence. Height 5 ft. 4 in., Weight, 8 stone.
14	2/Lt. J. C. ..	19 4/12	350	19,000	10,000	52	4,200	1,800	180	50	Home Defence 5 months. Before that Nieuport in France 300 hours. Then sent home for rest.
15	Lt. R. N. H. ..	27 6/12	330	22,000	10,000	77	3,900	1,400	80	57	Home Defence 5 months. Before that Scout France 6 months. Average height 16,000. Then home for rest.
16	Capt. H. C. T. ..	25	300	18,500	5,000	35	3,900	1,700	60	29	In France 9 months on Scout. Back 9 months. Now instructing. Had been up in morning, examined in afternoon.
17	Fl. Lt. L. B. F. W.	19 7/12	275	18,500	12,000	58	3,600	1,100	100	13	Off Scouts for 8 months. Now instructing.
				Average	..	57	3,897	1,423	95	40	

TABLE XI

No.	*Name and rank.*	*Age.*	*No. of hours flown.*	*Maximum height.*	*Average height.*	*Time breath held in secs.*	*Vital capacity in c.c.s.*	*Supplemental air in c.c.s.*	*Expiratory force in mm. Hg.*	*Time in secs. of supporting 40 mm. Hg by blowing.*	*Remarks.*
1	2/Lt. J. D. H. ..	18 10 12	67	13,000	5,000	66	3,900	1,500	100	55	Training for scout.
2	2/Lt. A. P. H. ..	18 10 12	60	10,000	5,000	55*	3,500	1,250	60	40	Training for scout. *Swimming in head.
3	2/Lt. J. M. B. ..	26 5 12	20	6,000	3,000	95	3,700	1,300	100	71	Training for scout.
4	2/Lt. A. B. G. ..	33 6 12	80	12,000	2,000	71	3,450	1,200	140	47	Training for scout.
5	2/Lt. F. A. ..	21 3 12	15½ s	6,000	2,000	45	3,000	950	70	40	Training for scout.
6	2/Lt. B. I. ..	24 2 12	12	5,000	2,000	68	4,200	1,800	110	58	Training for scout.
7	2/Lt. R. J. L. ..	31 10 12	70	15,000	5,000	72	4,850	2,050	100	54	Just finished training for scout.
8	2/Lt. R. A. B. ..	19	95	16,000	5,000	46	3,750	1,600	60	47	Training for scout. Had been up 2 hours in the morning; examined afternoon.
9	2/Lt. L. H. C. ..	18 10 12	40	12,000	3,000	45	3,700	1,200	100	42	Training for scout.
10	Lt. M. L. H. ..	25 3 12	35 180 *o*	16,000	7,000	57	3,900	1,200	120	50	Training for scout. Up 1 hour 15 minutes in morning; examined afternoon.
11	2/Lt. P. J. N. ..	20 2 12	35 180 *o*	14,000	7,000	53	3,400	1,300	80	45	Just qualified for scout.
12	Lt. T. T. S. ..	26	130	13,000	8,000	66	4,500	1,700	130	48	
13	2/Lt. S. C. W. ..	23 6 12	70	16,000	6,000	61	2,850	1,200	85	36	Small physique.
14	2/Lt. K. J. B. L.	27 4 12	60	14,000	5,000	76	4,450	1,700	80	50	
15	Lt. F. L.	25	116 *o* 16 *p*	22,000 *o*	16,000	55	4,150	1,600	119	50	
			Average ..	..	..	62	3,820	1,433	96	49	

s = Solo *o* = Observer. *p* = Pilot.

about normal standard. Further experiment is required, however, to see what amount of flying is necessary before lasting deterioration takes place and flying stress gradually creeps in. It will undoubtedly be found to vary greatly, as seen above, in individual cases. Some pilots will manage two 'shows' a day with ease, others will not.

The after effect of a straightforward five-hour flight on a delivery pilot is given below; he was a big man weighing over 13 stone, and was not examined until 24 hours after the flight.

Lt. D. W. H. . Age $29\frac{6}{12}$.
Flying 300 hours.
Maximum height 16,000, average 4,000.
Breath held 80 seconds.
Vital capacity 3,500 c.c.
Supplemental air 1,100 c.c.
Expiratory force 40 mm. Hg.
Sustaining 40 mm. Hg 21 seconds.

In contrast to this case is that of Capt. B. E. B., who served $10\frac{1}{2}$ months strenuous flying on high-flying machines overseas. After thorough examination at Etaples by the late Lieut.-Col. Corbett, who found him practically unaffected by altitudes (Dreyer's method), he was examined at Hampstead with the following result:

Capt. B. E. B., D.S.O., M.C. . Age $21\frac{4}{12}$.
Flying 1,000 hours.
Maximum height 22,000 feet.
Average height 15,000 feet.
Breath held 110 seconds.
Vital capacity 4,250 c.c.
Supplemental air 1,700 c.c.
Expiratory force 180 mm. Hg.
Sustaining 40 mm. Hg 57 seconds.

During the last test the pulse rate gradually increased from 66 to 84 per minute. Such a subject is undoubtedly a super-high altitude flyer. This is particularly brought out by a comparison of the above results with those on pilots who have broken down and have been taken off flying through stress of service, a stress more marked in some cases than others (Table XII, pp. 116–18).

These results show that in such subjects there is a marked falling off in the ability to perform the tests. It will be noticed that the subjects are for the most part high altitude flyers. The two officers (Nos. 10, 22) who almost attain the normal standard in sustaining mercury at 40 mm. with the breath held, had been off flying for some months past.

The value of the tests may be set forth by collecting the *average* results into a table (Table XII).

From the above figures it would appear that for the expiratory force test 80 mm. Hg should be taken as a minimum. For the test of sustaining 40 mm. Hg with the breath held, 40 seconds should be regarded as the minimum time. If below this it would appear advisable to limit flying both as to hours and height, and if much below this figure, to take the subject off flying for a time altogether.

TABLE XII

No.	*Name and rank.*	*Age.*	*No. of hours flying.*	*Maximum height.*	*Average height of all flying.*	*Time breath held in secs.*	*Vital capacity in c.c.s.*	*Sapphoscopal acc. in c.c.s.*	*Expiratory force in mm. Hg.*	*Time in secs. of holding 10 mm. Hg by bloodpressure*	*Remarks.*
1	Flt. S. Lt. R. F. .	22 6 12	600	22,000	10,000	39	4,000		50	15	200 hours France at average 18 20,000. Gradual onset of disability to fly high. Cardio-vascular system good, nerves good.
2	2 Lt J. K. C. ..	20 9 12	200	21,000	10,000	61	4,000	—	50	19	High flying on D.H 4. Feels effects after 3 weeks.
3	Lt J H. C. ..	20 1 12	400	13,000	10,000	52	3,200	1,400	80	25	Lately delivery pilot. Before that D.H. 2 in France. 'Fed up with flying.'
4	2/Lt. A. H. W.	24 10 12	75	15,000	10,000	63	4,000	1,700	100	37	Scouts in France 4 months. Back 1 week. Fainted at 6,000 after stunting for 1 hour.
5	2 Lt. W. D .	26 6 12	100	21,000	12,000	55	3,700	1,000	60	29	Five months Scout. Fainted after coming from 15,000 to 5,000 quickly. No flying for 3 months.
6	2 Lt. G. H. S. ..	24 3/12	170	15,000	12,000	45	3,450	1,000	80	21	On Scout in France 3 months. Back 1 week. Cardio-vascular debility and splashing stomach.
7	Flt. S/Lt. E F.B.	23 8 12	100	18,000	14,000	40	2,650	450	40	5	60 hours Scout and high flying bombers. Slight physique. Headache and gradual breakdown. Influenza 1 month ago. Off flying 6 months.
8	Capt. C. N. J ..	21 3 12	200	19,000	12,000	50	3,450	1,600	42	3	France 100 hours Scouts, then wounded.
9	Lt. E. B. G. ..	21 4 12	700	20,500	12,000	43	3,450	600	50	25	450 hours on Scouts in France, then shot down 5 months ago.
10	Capt. R. M. F.	22 8/12	460	18,500	10,000	68	4,000	1,700	120	45	Scouts in France, came home with 'nerves'. No flying for 4 months past.

11	Capt. G. N. M.	23 8/12	460	16,000	12,000	64	3,500	1,100	50	27	Scouts France 100 hours D.H. 5. Before that instructing 5 months. Before that Scout France 8 months. (D.H. 2.)
12	Lt. C. S. L. ..	21 6/12	200 125 o	22,000	13,000	63	3,550	1,600	125	23	Lately Home Defence 2 months. Taken off flying by M.O. Before that 5 months Scout France.
13	Lt. E. M. G. ..	26	150 150 o	16,500	5,000	37	3,600	750	45	23	Home Defence 6 months. Before that in hospital for nerves and headaches after flying Scouts in France.
14	Lt. W. L.	29 7/12	900	16,000	7,000	23	2,600	700	50	20	Exercised after one month's leave. Lately instructing 350 hours in nine months. Before that testing 18 months. Average height 10,000 ft. Now "fed up with flying" and stood off by M.O.
15	2 Lt. W. F. W.	20 6/12	350	20,000	10,000	40	3,250	1,200	110	37	Back from France for rest 2 months after 80 hours Scouts (average 18,000 ft.) Flying Mechanics in 1916. Now starting Instructional flying.
16	Lt. W. A. W. ..	25 6/12	80	13,000	8,000	54	3,600	1,300	80	27	Back from France 5 days. Seven 40 hours. Now suffers giddiness during climbs, particularly in dives.
17	Capt. S. J. S. ..	29 6/12	300	20,000	14,000	59	3,600	1,300	140	31	Back from France 5 days. Seven on active service 250 hours. Could not possibly do more in Flying Mechanics.
18	Lt. J. J. P. ..	25 11/12	140	13,000	10,000	60	4,100	—	70	35	Shot down [illegible] aggravated by flying aphonia. Now instructing.
19	Fl/Lt. E. J. C. ..	21 1/12	300	11,000	3,000	44	3,200	600	90	37	Five hours passed for service. Five weekly for 6 months past. Before that Scouts one month, and suspect 12 months. Stood off for rest.
20	Lt. T. F. A. ..	22 3/12	1,575	10,000	2,000	60	3,800	1,800	60	33	3 years 6 months active [illegible]. Now 3 months for damaged [illegible].

O = Observer.

TABLE XII (*continued*)

No.	*Name and rank.*	*Age.*	*No. of hours flying.*	*Maximum height.*	*Average height of all flying*	*Time held breath in secs.*	*Vital capacity in c.cs.*	*Supplemental air in c.cs.*	*Expiratory force in mm. Hg*	*Time in secs. of holding 40 mm. Hg by bloaters.*	*Remarks.*
21	2/Lt. W. A. McC.	19 6/12	110	15,000	4,000	25	3,900	1,600	45	16	Possibly oxygen want. Delivery Pilot 3 months, now stood off. Before that D. H. 4s. France one month, which knocked him up.
22	Capt. F. H	29 6/12	600	14,500	10,000	58	3,100	800	100	45	Off flying 8 months. Flew 4 months with malaria and got absolutely knocked up. Very nervous. Has just started flying a little. Now feels keen.
23	Lt. J. H. C.	29 3/12	400	13,000	10,000	52	3,200	1,400	80	25	Flying D.H. 2 in France. Then Test and Delivery Pilot. 'Fed up with flying.'
24	Lt. G. S. W.	26 8/12	65	15,000	12,000	42	3,800		80	22	Could not stand high flying, two crashes following high flights.
25	2/Lt. C. N. H.	21 6/12	50	10,000	5,000	38	2,300*	500?	80	20	Training for Scout. Fainted 10,000 ft. Eight crashes due to bad landings. Admitted A.B. Held breath on admission 43 seconds. Oxygen used 312 c.cs. per kilo per hour.
26	Capt. W. W. H.	28 1/12	500	13,000	5,000	38	3,500	850	50	18	Instructing 6 months. Before that France 250 hours. Average 8,000. Fainted in air. Felt very bad.
27	Lt. C. F. E.	33 6/12	200	14,000	6,000	37	3,400		75	20	Artillery observation 120 hours. Delivery Pilot since Nov. Now tired after long trips.
				Average		49	3,480	1,134	74	25	

* Maximum of 4. † Average of 5.

TABLE XIII

Subjects.	*Number examined.*	*Breath held in seconds.*	*Vital capacity*	*Supplemental air*	*Expiratory force mm. Hg.*	*Sustained 40 mm. Hg.*	*Remarks.*
Fit instructors	22	*67	4,062	1,620	112	52	* Average.
Ditto		46	3,300	1,000	80	43	Minimum.
Fit Home Defence pilots	24	72	3,940	1,496	119	50	One or two suffering from stress included in the table.
Fit British candidates	23	69	3,823	1,590	106	52	
U.S. candidates	7	66	3,814	1,386	116·4	53·5	
Delivery and test pilots	10	57	3,620	1,050	108	40	
Pilots returned for rest	17	57	3,897	1,423	95	40	
Pilots training for scouts	15	62	3,820	1,433	96	49	
Pilots taken off flying through stress	27	49	3,480	1,134	74	25	

In addition to these subjects, a large number of hospital cases have been examined. The results of many of these are given in Tables XIV and XV (pp. 120–21 and 122–25).

In addition to the poorness of the performance with the 40 mm. Hg 'fatigue' test, the smallness of the vital capacity (e.g. Case No. 13, Table IV, and of the supplemental air is very noticeable in many cases. Taking 80 mm. Hg as the minimum for expiratory force and 40 seconds as the minimum for sustaining 40 mm. Hg with the breath held, it would seem that after injury following crashes, particularly after injury to the head, the subject fails at the tests. This would indicate that the *tests will be of value in assessing the degree of shock sustained by a pilot in so-called 'minor' crashes.* It is of interest that 'psychopaths' (determined by the neurologist) pass the tests quite well, whereas subjects suffering from nervous symptoms due to flying stress fail. With a history of flying after dysentery or malaria, the subjects frequently fail at the tests (cf. also Table XV), confirming the opinion already formed as to the injurious effects of these diseases. It is also of interest that a case of indigestion (No. 11) and a case of blindness in one eye (No. 32), examined without the history being taken, pass the test. In neither subject was there reason to suppose that there was any stress of service. It should be noticed, however, that, generally speaking, almost *all the hospital cases examined (except psychopaths) fail to pass the tests.*

In Table XV there is no attempt to differentiate between officers who came to the hospital suffering from stress of service, and other cases, surgical or medical.

In this table, however, is also included a column showing the pulse response during the time that the mercury is being sustained at 40 mm. with the breath held, otherwise the same remarks apply to this as to Table XIV.

From Table XV it will be seen that the counting of the pulse during the sustaining the 40 mm. Hg test (with the breath held)

TABLE XIV

No.	*Name and rank.*	*Age.*	*No. of hours flying.*	*Maximum height.*	*Average height.*	*Time breath held in secs.*	*Vital capacity in c.cs.*	*Supplemental air c.cs.*	*Expiration force, in mm. Hg*	*Time in secs. of supporting 40 mm. Hg by blowing.*	*Remarks.*
1	2/Lt. J. R. F. ..	27	80	12,000	2,500	62	3,500	1,300	90	45	Primary psychopath.
2	Lt. J. C.	24 8/12	150 *o* 4 *d* 10 *s*	10,000	6,000	93	3,750	1,200	70	53	Psychopath. Possibly some fatigue.
3	2/Lt. C. F. S. ..	19 3/12	24 *s*	8,000	3,000	38	3,100	800	70	19	Neurasthenia following crash (concussion).
4	P. F. O. F. W ..	18 9/12	9 *s*	5,000	1,500	52	2,500	1,100	70	37	Resting after crash—bashed head against fusilage.
5	2/Lt. W. R. W.	19 2/12	1 *d*	—	—	92	4,100	1,800	80	50	Asthma.
6	Lt. W. D. ..	26 6/12	100	21,000	12,000	–	3,700	1,000	60	29	Cardio-vascular debility. Fainted after coming.
7	2/Lt. G. L. T ..	29 1/12	45	8,000	5,000	53*	4,100	2,000	76	40*	Anaemia (very marked). *Giddy.
8	Lt. E. W. C. ..	29 6/12	200	17,500	4,000	50	3,400	1,100	140	43	Back from France 5 days. Night flying. Bronchitis.
9	2 Lt. R. I. W. ..	20 7/12	20min	—	—	38	2,700	1,100	60	30	Gastric trouble.
10	2/Lt. R. H. T	19 7/12	20 *d* 2 *s*	3,500	1,000	72	3,450	1,400	50	51	Crashed—hurt foot, always making bad landings.
11	2/Lt. J. S. ..	24 2/12	11 *d* 30 *s*	10,000	5,000	75	3,800	1,000	180	64	Indigestion.
12	2 Lt. R. H. D. ..	18 5/12	100	14,000	3,000	45	3,400	850	110	40	Tonsillitis. Had a cold at time of examination.
13	Capt. S. E. G. ..	26 2/12	300	12,000	7,500	30	1,500 (3 attempts)	—	45	12	Crashed Feb. 17—concussed. Now dizzy at 5,000 or over. Fainted at 8,000. Test gave him headache. Inspiratory force 60 mm. Hg. Sustaining 40 mm. Hg by inspiring 12 seconds.
14	Capt. A. S. C	21 9/12	150	8,000	2,500	68	4,500	—	60	28	Malaria.
15	2 Lt. G. W.	32 4/12	8	1,600	1,000	48	3,100	1,000	100	18	Neurasthenia following crash. Stomach trouble, sickness and diarrhoea after landing.
16	2 Lt. E. T. D. .	32 5/12	3 *d*	4,000	1,500	42*	3,500	800	38	3	*Giddy.
17	2/Lt. R. W. T. ..	21 5/12	23	9,500	3,500	45–72	3,500	1,000	80	40	Enteric and sunstroke.

o = Observer. *d* = Dual. *s* = Solo.

18	2/Lt. T. T. ..	28	11/12	300	14,500	9,000	42	3,600	900	80	35	Dysentery. Instructing last 7 months. Before that France 8 months. Average 9,000 ft.
19	Flt.-Lt. F.D.H.B.	24	10/12	150	13,000	10,000	59	4,400	1,600	110	39	No flying 18 months. Trench fever and malaria.
20	2/Lt. E. N. C. ..	19	10/12	5½d 1 s	2,000	—	30	3,600	1,100	130	22	Cardio-vascular debility. No A.B. examination. Has had malaria.
21	E. T. M. .. .		19	60	5,000	2,000	35	3,200	1,150	50	20	Oxygen want. Throbbing in head. No A.B. examination. Bad landings.
22	2/Lt. P. R. ..	28	9/12	100	15,000	3,500	65	3,500	1,300	105	45	Premature contractions following influenza. Night bombing 25 hours.
23	Flt.-Lt. G. A. M	21	6/12	175	15,000	10,000	94	4,100	1,300	140	75	Shrapnel wound in head May 17. No flying since.
24	Capt. R. G. M...	22	11/12	1,500	23,000	10,000	40	4,100	1,750	60	28	Nerves gone. Has fainted in the air. Limited flying since Dec. 17 due to synovitis of knee. Before that Scout in France (250 hours).
25	2/Lt. D. D. P. ..	20	4/12	75	12,600	3,000	30	3,200	1,100	60	20*	Dilation of heart (influenza), 'nerves', dyspepsia. *Females turn red.
26	2/Lt. W. B. ..	18	10/12	13 s	10,000	2,000	44	3,400	900	60	18	'Nerves', crash, and impressions. Sent to hospital 4 days.
27	Lt. C. B. L. ..	27	6/12	8d	[illegible]	[illegible]	44	3,000	1,000	80	35	In hospital since crash (August), much serious fortnight. Many fainting.
28	Lt. W. B. H .	25	9/12	100	9,000	4,000	44	2,000	550	60	25	Instructing M.T. Tension, perspiration.
29	2/Lt. L. L. .	19	3/12	15 s	7,000	6,000	29	3,200	200	45	22-19	'Nerves', crash, thrown over head, [illegible], then went dazy. Still [illegible] Army.
30	Capt. A. S. L. ..	23	6/12	100	23,000	15,000	55	4,000	1,300	140	45	Scouts nearly all time. From France Jan. 8, 8 months (300 hours, [illegible] 10,000'). One leave 14 days beginning November.
31	2/Lt. F. C. ..	21	8/12	200	22,000	16,000	45	3,500	1,300	80	42	From France Jan. 19, 4 months flying Scouts (S.E. 5), 200-240 hours. Run down—home on leave.
32	Capt. G. C. M. ..	34	7/12	250	18,000	12,000	66 (8)	3,800	1,400	130	47	Defective eyesight. Left eye useless. Makes good landings. Left France 2 days. Since July flying Scouts in France 140 hours, [illegible] 12,000, before that 'ground training' 2,000 ft.

O = Observer. D = Dual. S = Solo.

TABLE XV

No.	*Name and rank.*	*Age.*	*No. of hours flying.*	*Maximum height.*	*Average height.*	*Time breath held in secs.*	*Vital capacity in c.cs.*	*Supplemental air in c.cs.*	*Expiratory force in mm. Hg.*	*Time in secs. of supporting 40 mm. Hg by bleeding.*	*Pulse response.*	*Remarks.*
1	Maj. S. G. S. ..	24 7/12	600	15,000	10,000	77	4,500	1,800	110	46	84–132 and maintained	Psychopath.
2	2/Lt. C. W. M. ..	25 11/12	140	13,000	10,000	46	3,750	1,300	140	41	60–96 and maintained	Last 2 months Italy. 4 months active service, 70 hours, average height 10,000.
3	Lt. P. J. W. R.	24 11/12	40	11,000	10,000	69 (8)	3,500	800	60	22	72–108–60	From France. Enteric 18 months ago. Crashed first time up, 6 weeks in France.
4	Lt. A. N. A. ..	26 11/12	200	19,000	8,000	85 (8)	4,100	1,250	160	65	90–100 and maintained	From Italy and France R.E. 8. Average 8,000, 80 hours. Instructing England. Crash, injury to stomach and head, Nerves gone.
5	2/Lt. W. R. B. ..	19 5/12	10 *d* 5 *s*	10,000	2,000	41	3,200	1,200	70	24	84–108 and maintained	Blow on head from propeller. Headaches.
6	Lt. H. W. T. ..	21 1/12	65	17,000	10,000	62	3,500	1,000	80	25	78–108–78	From France, D.H. 4, 3 hours. Crash, blow on eye. Headaches since.
7	2/Lt. I. V. H. ..	30 6/12	200* 60†	18,000	7,000	55	3,900	1,800	120	41	72–84 and maintained	Headaches, neurasthenia. Limited flying, not above 3,000 ft.
8	2/Lt. H. O. ..	28 1/12	130 *o*	12,000	2,000	37–49	3,400	1,000	85	19	72–120–96	Artillery shoots. From France. Crash August 12th. Unconscious.

9	2/Lt. D. S. R. ..	20 9/12	100	17,000	14,000	35	3,750	1,150	115	25	72–96–72	From France. Crashed. Unconscious Oct. 2 17. Hospital since. 8 hours 30 hours.
10	Lt. B. L. B. .	23 6/12	100 *o*	10,100	5,000	43	3,350	800	80	35	78 108 96	From France (24). History of crashes.
11	2/Lt. R. C. ..	19 6/12	450	18,000	8,000	46 (8)	4,200	850	64	43	60–72 headaches	Indy. R.E. 8. Average 8,000. Photographic. Home on leave. Did not feel fit to go back.
12	Lt. B. T.	22 6/12	160	19,500	14,500	72 (8)	4,000	850	120	35	66–96 and varying	From France. In Hospital 1 week. S.E. 5. 4 months overseas, 60 hrs. England 100 hrs. Average 4,000. Shell burst at 17,000 over Cambrai. Managed to get back at 2,000.
13	2/Lt. A. C. ..	24 8/12	160	18,000	12,000	50	3,400	800	100	33	66–108–72	From France. Three crashes. Bad landings. S.E. 5, 100 hours. Average 12,000. Training in England.
14	Lt. A. G. G. ..	24 9/12	160	18,500	14,000	52	3,500	1,000	120	34	72 96–72	From France. Colossal wind up. D.H. 4, no oxygen. Average height 16,000. Since July 120 hours. Can't imagine any machine can be worse, unless he still has time to get into aeroplane.
15	2/Lt. W. O'T. ..	25 3 12	150 *o* 10 *p*	22,000	18,000	40	3,500	—	60	45	72 120 and maintained	Bristol fighter 148 hours. Crashes. In hospital two months, head cut, eye damaged. During training at Hounslow. Crashed from 200 ft.

d = Dual. *s* = Solo. † = R.N.A.S. ‡ = R.F.C. *o* = Observer. *p* = Pilot.

TABLE XV (*continued*)

No.	*Name and rank.*	*Age.*	*No. of hours flying.*	*Maximum height.*	*Average height.*	*Time to attain height in secs.*	*Vital capacity in c.c.s.*	*Supplemental air in c.c.s.*	*Expiratory force in mm. Hg*	*Time in secs. of supporting 40 mm. Hg by blowing.*	*Puls. response.*	*Remarks.*
16	Lt. N. V. B. ..	21 7/12	250 *o* 190 *p*	20,000	14,000	99 (S)	4,200	1,700	90	48	72–96	From France 10 days, S.E. 5—6 months. (140 hours.) 17,000 average.
17	2/Lt. C. W. S. ..	19 4 12	55 *p*	14,000	5,000	43 (S)	3,700	1,000	50	27	72–96 and maintained	From Italy. 20 hours. Average 4,000. Home for further instruction. 'Nerves' 7 hours ago.
18	2/Lt. H. M. M.	20 1 12				66	4,200	1,800	120	35	84–132 and varying	No flying. Reading. Admitted A.B. Fractured pelvis 9 weeks ago.
19	Lt. C. W. P. ..	29 2 12	50	8,000	4,000	22 (S)	3,750	00	70	23	108–132–96 varying	In hospital, fractured nose. 'Nerves.'
20	Lt. C. R. G. ..	28 9 12	90	15,000	7,000	48 (S)	3,300	1,600	90	17	72–108	Fractured skull, 25 Sept. '17. Scar on face by gun mounting. Lost consciousness 10,500. Next thing staggering about ground. Was going on sick leave.
21	Lt. S. C. B. ..	35 6 12	50	10,500	5,000	71 (S)	—	—	100	45	90–132–96 varying	Flying F.E. night. Crashed Feb. 15. Shaken up. Hospital R.E. 8 (8 hours).
22	Lt. F. A. P. .	26 6 12	80	10,000	5,000	41	—	—	80	25	72–96–72	France S.E. 5 (10 hours). Crashed twice in 3 days. D.H. 5 (10 hours).
23	2/Lt. A. B.	21 1/12	5 *d* 3 *s*	6,000	2,000	37	-	—	100	27	72–120–96 varying	Crashed (stammer since). Flying continued. Bashed head with crash helmet.

24	Lt. W. A. R. D.	27 4 12	40 *a*	22,100	2,000	55			100	35	84 144 132	From France. 8 weeks Bristol fighter overseas. 15-20,000 average. Lost confidence suddenly.
25	Maj. G. A. C. ..	36	800	10,000	3,500	25	2,500	1,200	80 (giddy.)	20 (headache.)	72 78 4	Dysentery, malaria, flying in all countries, but not feeling fit since illnesses.
26	Capt. M.C.F.R.	25 7 12	650	17,500	5,000	82	4,200	1,600	100	38	84 108 and maintained	From France 4½ months. Night flying (average 5,000) 16 months.
27	2 Lt. J. C. M. ..	19	65	12,500	5,000	61 (8)	4,400	1,800	120	53	84 108 60	Training for scout.
28	2 Lt. E. S. P. ..	21	140	19,500	16,000	30	4,000	1,100	60	15	60 96 and maintained	From France. 5 months. Average 16,500 90 hours. Egypt 3 months. 30 hours average height 8,000.
29	Lt. H. T.	30	250	18,000	10,000	90	3,800	1,020	65	41	72 132 108 varying	Fractured base 8 weeks ago.
30	Fl. S/Lt. F. E. D.	24 7 12	100	16,000	2 3,000	72	3,950	1,800	80	59	78 96 maintained	Perforation ear and fractured base 2 months ago.

a — Observer. *p* — Pilot. *d* — Dual. *s* — Solo.

affords valuable indication of the degree of stability of the cardiomotor centre. It had previously been found that counting the pulse during holding the breath does not give sufficiently striking differences on which to generalize. The late Lieut.-Col. Corbett, R.A.M.C., however, informed the writer that, during the Dreyer altitude test (see Report No. 4) he had noticed a difference in the response of the pulse between normal and abnormal individuals, and observation of the pulse behaviour as a routine procedure while holding 40 mm. Hg was in the main an outcome of this piece of information. From comparison with Col. Corbett's notes it would seem that the results are fairly comparable during the two tests.

The exact significance of the pulse response has yet to be worked out in detail in regard to the various types of hospital cases. Generally speaking, it may be stated that, starting at the 5th second, there is in the normal individual a steady low rise in the rate of the pulse (cf. Capt. B. E. B.), or a fairly marked rise, which is sustained most of the time. For example, the pulse rate may rise gradually from 72 per min. to 96 or 108, according to the time the breath is held, or the pulse may rise almost at once from 72 per min. to 98 or 108 and be maintained there. A large rise in rate, for example, from 72 to 132 or 144, is, generally speaking, unsatisfactory. In the case of Fl.-Lt. B. (No. 7, Table XI), who could only sustain 40 mm. Hg for 5 seconds, it was found that when 20 mm. Hg was held for 10 seconds the pulse rate rose from 96 to 168 per min., becoming almost impalpable.

In cases of flying stress with cardio-vascular symptoms, a characteristic response seems to be for the pulse to jump quickly up during the 5th to the 10th or 15th second, and then to fall away in rate to normal or even considerably below normal. Such a response is as follows :

> Normal at start 84 per min.
> 5th to 10th second 144 (or almost imperceptible).
> Falling away (say 20th to 25th second) to 72 or 60.

Such cardiomotor instability is frequently found in officers in need of a rest.

The results, however, apply equally well in the case of candidates (cf. Table XVIII, p. 129). In this table it will be seen that the results as a whole are in accordance with those found in the general examination, and the test is regarded as yielding valuable evidence in cases of doubt.

The value of the tests from the point of view of the examination of candidates is also illustrated by Table XVI (p. 127). In this table are seen results of the examination of (Nos. 1–13) candidates previously definitely rejected by the assessors, and (Nos. 14–18) five candidates whom the examining medical officer or the assessor 'did not like the look of'.

It will be seen that these cases are all found unfit in some respect or other by the tests employed. Further experience has fully confirmed the value of these tests in the selection of cadets.

It should be mentioned that the tests have been found useful in determining the degree of fatigue in observers coming from high flying squadrons in France for admission as pilots. Most of these

TABLE XVI

No.	Name	Age	Time breath held on exhaustion. seconds.	Total capacity c.c.	Supplemental c.c.	Expiratory force in mm. Hg.	Length of sustainment at 40 mm. Hg by blowing.	Remarks.
1	G. E. B.	17 11/12	55	4,200	1,300	80	42	Rejected.
2	W. D. H.	17 11/12	84	4,300	1,800	60	25	Rejected.
3	J. McK.	18	53	3,700	1,700	55	32	Rejected.
4	H. G. R.	18	66	3,800	1,650	130	30	Rejected.
5	H. B.	17 11/12	53	2,800	1,000	60	25	Rejected.
6	R. R. S. A.	18	48	3,600	1,650	70	27	Rejected.
7	W. M.	17 11/12	44	3,400	1,600	120	35	Rejected.
8	R. C. T.	18	85	2,750	900	100	28	Rejected.
9	H. E. S.	17 11/12	71	2,400	1,050	100	50	Under [illegible] standard.
10	F. R.	19	50	3,100	1,000	60	20	Rejected.
11	D. H.	19	63			60	40	Rejected.
12	C. T. M. H.	19	42	3,800		40	33	Rejected.
13	2/Lt. C. H. S.	23	42	4,200		60	25	Rejected.
14	W. A. B.	18 1 12	64	-		60	33	M.O. says he does not like him. Referred by assessor.
15	2 Lt. F. W. C.	22	61	4,100		100	30	Assessor did not like the look of him.
16	F. C. B.	23 2 12	63	4,300	1,800	60	35	Assessor did not like the look of him.
17	F. R. B. W.	21 6 12	55	4,100	1,700	80	37	History of Migraine referred by assessor.
18	C. T. Y.	18 2/12	48	3,800	1,700	100	35	History of Migraine referred by assessor.
	Average		58	3,650	1,450	77	32	

show considerable improvement after three weeks' leave, but in a certain number there is still such a degree of stress that they are not fit to go at once into training. Such subjects usually state that they have had a strenuous time and ask if it is not possible to get a ground job or a little rest. When examined with all precautions against deception by the subject, they invariably fail to pass the tests.

A few sample figures are given in Table XVII (p. 128).

It should be mentioned, however, that other candidates, although having had similar flying experience, pass the tests, again exemplifying the greater proneness to fatigue of some systems than others.

In Table XVIII are given more results on candidates taken haphazard together with the pulse response during the sustaining of 40 mm. Hg. In the 'Remarks' column are given the assessor's findings, which were not known at the time of the examination.

E. Prognosis.

In regard to cases of flying stress it is too soon to venture an opinion as to the rate of recovery. It would seem, however, that the recuperative power of some subjects is greater than of others.

TABLE XVII

No.	*Name and rank.*	*Age.*	*No. of hours flying.*	*Maximum height.*	*Average height.*	*Time breath held in secs.*	*Vital capacity in c.c.s.*	*Supplemental air in c.c.s.*	*Expiratory force in mm. Hg.*	*Time in secs. of supporting 40 mm. Hg by blowing*	*Remarks.*
1	Lt. A. G. T. ..	23 4/12	160	13,000	5,000	62	3,600	800	90	32	Flying 7 months. Observer R.E. 8.
2	2/Lt. A. B. S. ..	21 3/12	160	22,000	17,000	50	3,000	—	110	35	Observer Bristol fighter.
3	2/Lt. H.	23 1/12	120	20,000	17,000	45	3,200	1,200	70	31	Observer D.H. 4.
4	2/Lt. F.R.S.W.	24	130	22,000	18,000	35	—		60	30	Observer D.H. 4. Pulse 84-96 and maintained.
5	2/Lt. N. P. ..	22	105	20,000	17,000	43	3,600	1,300	60	27	Observer D.H. 4. Pulse 84-20-96.
6	2/A. M. W. B. L.	24	102	12,000	8,000	45	—		100	38	Observer R.E. 8. Pulse 84-32-72

TABLE XVIII

No.	Name and rank	Expiratory force in mm. Hg.	Time in seconds of sustaining 40 mm. Hg.	Pulse before exercise	Pulse response	Remarks
1	Lt. A. B. G. ..	110	35	96	120–108 varying	100 hours observer D.H. 4.
2	Lt. H. ..	70	31	84	120 maintained	Unfit.
3	Lt. M.	100	35	84	144–132	Strenuous time in trenches. Unfit.
4	Cadet C. ..	60	28	72	108–72	Unfit C.V.D.
5	Cadet W. ..	120	48	84	108 maintained	Fit.
6	Cadet C. ..	120	57	90	120–108	Fit.
7	Cadet S. ..	90	40	60	84–48	Unfit.
8	Cadet L. T. S. ..	130	35	90	Imperceptible 96	Unfit.
9	Lt. G. C. ..	80	41	96	144–108	Unfit.
10	2 Lt. C. T. M. H.	40	33	84	132 varying	Unfit.
11	2 Lt. H. W. L.	100	50	72	84 maintained	Fit.
12	2/Lt. R. E. R...	110	25	72	84 maintained	Malaria. Temporarily unfit.
13	Cadet E. G. M.	100	72	72	108 maintained	Fit.
14	Cadet D. H. ..	60	40	84	108–72	Unfit C.V.D.
15	Cadet D. G. P...	70	35	120	156–108	Unfit C.V.D.
16	Cadet R. W. ..	100	51	60	78 maintained	Fit. Slow intellect.
17	Lt. E. H. W. ..	60	34	96	120–72	Unfit.
18	Cadet W. A. S.	60	33	120	156–108	Referred by assessor. Found unfit.
19	2/Lt. C. H. S. ..	60	25	84	120–96	Unfit. Wounded twice. Strenuous time in trenches.
20	2 A.M. J. M. K.	120	33	120	108–72	D.H. 4 observer. Temporarily unfit.
21	2/Lt. A. B. J. ..	130	53	72	108 maintained	Fit.
22	2/Lt. F. ..	60	20	72	96 maintained	Unfit.
23	2/Lt. J. D. .	160	54	60	84 maintained	Fit.

It will be seen that the pulse response has in many cases afforded valuable information as to the candidate's fitness, especially when taken in conjunction with other tests.

The results of some cases which have been examined two or three times are given in Table XIX.

The improvement in the time the breath is held, the vital capacity, the expiratory force, and the fatigue test is noticeable in each case (except Capt. N.). The subject also stated that he was feeling much fitter. It would seem from the case of Capt. N. that it is important that, when a certain degree of flying stress has supervened, the subject should not be allowed to fly. Capt. N., for example, begged to be allowed to continue 'limited flying', but soon found that he was not equal to it.

The results on recruits before and after one month's special respiratory exercises also indicate a great improvement in physical efficiency, an opinion vouchsafed voluntarily by the subjects con-

cerned. Such results point to the value of special exercises during the period of convalescence from flying stress, as well as in its prevention.

Prevention.

It would appear that the great hope in regard to flying stress is the prevention of its onset.

During the stage of ground training it is possible that by suitable exercises during the course of physical training, as in training for boxing or under-water swimming, the respiratory mechanism may be trained to sustain the strain imposed by flying at high altitudes. It appears that such exercises should be directed particularly to developing the expiratory force and a good tone in the abdominal wall; to accustoming the body to periods of hard work with only a limited alveolar tension of oxygen available. For this purpose, it would seem that some forms of graduated exercises with the breath held would be particularly suitable. Care would, however, have to be taken in the development of such exercises to ensure that beneficial and not harmful results were attained. This could be controlled by the application of the tests here described (see Table XIX).

When flying is begun, the systematic use of oxygen, even at relatively low altitudes, is to be recommended. (See Report No. 5 of this volume.) By a judicious hyper-oxygenation at lower altitudes the onset of deep breathing and dyspnoea is prevented at higher altitudes, and, also, the secondary ill-effects due to oxygen want. The importance of efficient administration of oxygen in this respect cannot be overstated. The fact that some pilots are more easily fatigued than others indicates that, particularly in respect of high-flying machines, the pilots should be graded with reference to their capacity for high altitude flying. Such capacity would be better estimated after their first period of training. It is probable that many pilots who break down from stress on scout machines would have rendered a much longer period of service on lower flying machines. During this time, however, there is no doubt that physical exercises, judiciously employed, will also serve to avert the onset of stress.

In regard to pilots who break down early on scout machines, it would be advisable if, before being stopped from flying altogether, they were medically examined, with a view to testing their capacity for flying at lower altitudes.

During the period of training in the air the pilot should be carefully watched. It is perhaps not too much to say that with careful medical overhaul, an efficient body of delivery pilots might be salved from officers who at present are being deemed unfit for further instruction in flying altogether. This is especially true of pupils who are found unfit to fly high altitude machines.

An experiment in this direction was made at a special medical flight, with the result that quite a number of pilots were 'salved', some of whom afterwards rendered service overseas. These officers were all selected from pupils who had been considered unfit for further instruction in aviation.

In the preliminary overhaul of these officers by the tests described in this paper, the interesting fact emerged that most officers who were found to be temperamentally unfit to fly were (in many cases) found to be physically unfit, whereas the officers who were keen to continue flying were found to be fit from the standard of these tests. In all over 300 such officers were examined. A sample selection of these examinations is given in Table XV.

No. 13 in the table below, although found physically fit, was certainly temperamentally unfit. It was ascertained later that he was a truculent, cross-grained fellow, undisciplined, and caused a lot of trouble throughout his career. Another pupil (No. 15) had developed 'anxiety'. He was not examined by a neurologist but was probably a psychopath. He always experienced great anxiety while in the air and was certainly unfit to continue flying and definitely wished to give it up.

It is difficult to say whether in other cases the unfitness was induced by unsuitable work or whether the candidates were unfit for flying from the outset. Probably they were mostly fit subjects who reacted badly to the strain of flying.

The above results, however, indicate that the flying temperament in many cases goes hand in hand with physical fitness. In most cases it is only when the officer is physically unfit that the opinion is formed that he is unfit for flying, or he himself comes to the conclusion that he is unfit for flying and wishes to cease altogether.

F. Treatment.

In regard to treatment of cases broken down through flying stress, it is probable that the judicious employment of physical exercise may produce beneficial results. (See Table XIX.) Violent forms of exercise should be avoided, but riding and walking are to be advocated since they call for the expenditure of little nervous energy. Where physical exercises are employed, care must be taken that these are producing beneficial results. Help in this direction may be afforded by the tests herein set forth.

The treatment of a series of cases by oxygen inhalations in a special chamber similar to that employed in 'gas' cases would be of interest.

G. Discussion of Results.

In a preliminary paper such as this, it is not intended to attempt full explanation of the results obtained. The need of fuller information is great on so many points that the most that can be done is to discuss the results in a tentative fashion.

The results so far obtained indicate that when flying stress has markedly supervened, the power to hold the breath, vital capacity, supplemental air, expiratory force, and the power to sustain 40 mm. Hg by blowing, are all decidedly lessened. It also appears that the most delicate of these tests is that of attempting to sustain 40 mm. Hg pressure by blowing with the breath held. By this test it has been found possible to grade pilots according to their capacity for flying, a capacity adjudicated not by the writer but by others, such as the

TABLE XIX

No.	Name and rank.	Age.	No. of hours flying.	Maximum height.	Average height.	Time breath held in secs.	Vital capacity in c.cs.	Supplemental air in c.cs.	Expiratory force in mm. Hg.	Time in secs. of supporting 40 mm. Hg.	Remarks.
1	2/Lt. H.E.K.G.	19 6/12	2 hrs. 40 m.	2,500	700	74 69	3,000 3,400	— —	60 100	12 40	C.V.D. Fainted at 650 ft. After 2 months Convalescent Home.
2	Lt. E. M. G. ..	26	150 *a* 150 *p*	16,500	5,000	37 55 95	3,600 3,700 4,000	750 1,000 1,400	45 60 100	23 23 52	Stood off by Medical Officer. Fortnight later. Fortnight later.
3	Capt. C. S. T. L.	21 6/12	125 *a* 200 *p*	22,000	13,000	63 83	3,550 4,400	1,600 1,600	125 140	23 45	Stood off by Medical Officer. 2 months later.
4	Capt. R. G. N.	22 11/12	1,500	23,000	10,000	40 42	4,100 4,100	1,750 1,700	60 60	28 25	— 6 weeks later, after limited flying.
5	Capt. W. R. B	25	700	17,500	15,000	72 80	3,900 4,480	— —	110 170	43 58	Fatigue. ? C_2H_5OH. Three weeks after 'taking care' of himself.
6	Lt. H. A. J. ..	24	86	20,000	15,000	55 80	4,150 4,560	— —	120 130	35 46	? Auto-intoxication. 10 days later, after giving up smoking and alcohol.

		Pulse : Standing.	*After exercise.*	*Return to normal.*					
7	Bo.	96	120	30	—	3,580	—	86	22
		81	96	15	—	3,790	—	128	37
8	Br.	108	132	20	—	3,480	—	90	38
		96	108	15	—	4,000	—	114	64
9	Co.	96	120	40	—	4,080	—	78	22
		72	96	20	—	4,520	—	88	47
10	Re	84	108	25	—	3,980	—	72	38
		84	108	20	—	4,080	—	88	55
11	Mcf.	96	108	15	—	3,400	—	120	41
		60	72	15	—	3,360	—	155	44

Recruits before and after one month's special respiratory exercises. Upper line before, lower line after, training.

Recruits before and after one month's special respiratory exercises. Upper line before, lower line after, training.

o = Observer. *p* = Pilot.

TABLE XX

No.	*Name and rank.*	*Age.*	*No. of hours flying.*	*Maximum height.*	*Average height.*	*Time breath held in secs.*	*Vital capacity in c.cs.*	*Supplemental air in c.cs.*	*Expiratory force in mm. Hg*	*Time in secs. of supporting 40 mm. Hg by blowing.*	*Pulse response.*	*Remarks.*
1	2/Lt. C. P. A. ..	21 8/12	6 *h* 2 *s*	3,000	1,500	30	3,400	—	80	25	96-132-108	No question of wishing to continue to fly.
2	2/Lt. R. H. ..	28 3/12	10 *h* 4 *s*	18,000	5,000	62	4,100	—	130	43	96-132 and maintained	Keen to fly. Doing well at Hendon. Medical flight.
3	2/Lt. C. G. T. ..	19 8/12	5 *h*	5,000	1,500	30	3,000	—	60	18	108 inappreciable—72	Does not wish to go on. Feels he is a 'dud'.
4	2/Lt. J. A. B. ..	19	35	15,000	6,000	66	3,500	—	100	53	108-120-108	Keen to go on flying.
5	2/Lt. H. D. O'D.	23 6/12	5 *h* 5 *s*	5,000	2,000	10	2,900	—	40	8	72, pulse went thready and could not be counted	Has suffered from colitis. No wish to fly at present.
6	2/Lt. K. L. G. ..	24	5 *h* 10m *s*		—	50	3,100	—	100	40	72-84-72	Very keen to go on. Now at medical flight.
7	2/Lt. J. M. S. ..	32	—	2,000	—	32	—	—	70	20	84-132	One crash. No wish to go on flying.
8	2/Lt. H. D. L. ..	19	40	14,000	8,000	15	—	—	40	8	84 and inappreciable	No wish to go on. History of crashes and bad landings.
9	2/Lt. W. J. K...	19	5 *h* 8 *s*	10,000	3,000	29	2,900	—	60	12		Headaches after flying. No wish to continue.
10	2/Lt. A. C. M. ..	19 2/12	3 *h*			66	—	—	120	48	84-108	Keen to go on. Now at Hendon. Medical flight.
11	2/Lt. D. B. B. ..	18 6/12	5½ *h*	—		49	3,100	—	100	40	Fairly good	Keen to go on. Now at Hendon. Medical flight.
12	P/Fl. O J. G. J	18	4½ *h* 10 *s*	3,000	2,000	68	4,100	—	70	35	60-96-60	Crashed. No wish to fly again. Tremor eyelids and fingers.

L.	2/Lt. J. S. McC.	18 2/12	—	—	—	—		—	80	60	60–72 and maintained	Crashed 4th solo. Temperamentally unfit. Caused lot of trouble always.
14	2/Lt. H. D. W.	19 3/12	2½ *d*	—	—	—		—	60	25	Pulse becomes impalpable	Temperamentally unfit.
15	C. N. S.	18 4/12	7.53 *d*	7,000	6–700	61	—	—	100	52	84–96–72	Temperamentally unfit; fit physically.
			1.43 *s*	—	—	—	—	—	—	—	—	
16	W. R. R	27 7 12	6.30 *d*	—	—	—	—	—	—	—	—	Very keen.
			1.31 *s*	6,200	1,000	57	—	—	100	43	108–132	
17	J. W. P.	22 11 12	7.47 *d*	—	—	—	—	—	—	—		Temperamentally unfit.
			0.52 *s*	3,500	1,000	32	—	—	100	22	80–108	
18	A. E. R.	26 7 12	7.4 *d*	4,000	1,000	35	—	—	77	28	72–108	Temperamentally and physically unfit.
			2.36 *s*	—	—	—	—	—	—	—	—	
19	C. G. B.	23	5 *d*	—	—	68	—	—	100	43	101–132–120	Keen to continue flying.
			s	—	—	—	—	—	—	—	—	
20	B. W. N.	19 4 12	13 *d*	—	—	—	—	—	—	—	—	Temperamentally unfit, physically unfit.
			2 *s*	—	—	35	—	—	75	20	66–132–106	
21	R. E. Y.	19	3 *d*	—	—	26	—	—	70	18	80–108–96	Temperamentally unfit, physically unfit.
			4½ *s*	—	—	—	—	—	—	—	—	
22	E. McN. H. ..	29 9 12	7 *d*	—	—	24	—	—	70	15	108–144–132	Temperamentally unfit, physically unfit.
			½ *s*	—	—	—	—	—	—	—	—	

d Dual. *s* Solo.

squadron or flight commander, the aerodrome medical officer, or the Invaliding Medical Board.

The following explanation of flying stress is here put forward tentatively. It develops to the greatest extent in high flyers and is of gradual onset. The rate of this onset appears to be closely associated with the respiratory capacity and expiratory force of the individual, being slower in those well developed than in those in these respects less well developed.

A good respiratory capacity is necessary for the efficient intake of the rarefied air at altitudes, a good expiratory force for breaking out against the slip stream of the propeller and the contrary wind created by the rapid progress of the machine through the air. It is calculated that the force of this wind in a machine travelling at 100–120 miles an hour may on occasion amount to 60 to 80 mm. Hg, showing how necessary is a good expiratory force.

During an ascent the respiratory system is the first affected, owing to the lessened oxygenation of the blood in the rarer air, so that a hyperpnœa of gradually increasing intensity is developed. With increasing height all the accessory respiratory mechanism is called into play, especially with the onset of definite dyspnœa. At high altitudes, also, periodic breathing (Cheyne-Stokes) is not uncommon. At this stage there is frequently definite evidence of oxygen want, as manifested by the ashen face and blueness of lips.

The pulse is greatly quickened, nervous symptoms, subjective or objective, may be present (see Lieut.-Col. Birley's Report No. 1 in this volume). At this stage the strain thrown upon the various systems is exceptionally great, particularly so upon the bulbar centres regulating the respiration and the circulation.

It is suggested that when, as in high flyers, this strain is frequently repeated, these centres, particularly the respiratory centre, become affected in such a manner that the regulation of respiration is no longer normal.

In regard to the respiration, the power adequately to ventilate the system is reduced owing to loss of expiratory force, breathing becomes shallower, lessened oxygenation of the blood follows, bringing in its train secondary circulatory and nervous symptoms. This agrees with the results observed by Haldane, Meakins, and Priestley on 'gassed' cases.[1] (See also report by Corbett and Bazett in this volume, p. 18.)

As regards the circulatory system, there may result eventually a tachycardia or disordered action of the heart, due most probably to an altered condition of excitability of the cardio-motor centre. This is well shown in many cases by the characteristic response of the pulse during the test of sustaining 40 mm. Hg by blowing with the breath held.

As has been shown also with the onset of flying stress, the pulse pressure gradually increases, a condition due, it is believed, to a lax tone of the arterioles, resulting possibly from an altered state of stability of the vaso-constrictor centre. The altered state of tone of the vaso-dilator centre is exemplified by the marked, almost instan-

[1] Haldane, Meakins, and Priestley, *Journ. Physiol.*, 1919, lii, p. 420.

taneous flushing of the face, which follows in the fatigued subject on the smallest effort at blowing.

In respect of the suggestion that the respiratory centre fails first, it is interesting to note that Professor W. M. Bayliss has recently found in his work on shock that if an animal be left with a low blood pressure after the removal of a large quantity of blood, the medullary centres become insensitive to stimulation. When the blood pressure is raised and artificial ventilation continued, the vaso-motor centre may recover, but the respiratory centre does not recover more than to give three breaths a minute. (Personal communication.)

Although attention is here directed particularly to the bulbar centres, it is to be noted, however, that owing to 'anoxaemia' there is usually an effect upon the central nervous system generally. It is at this stage the pilot feels, for some reason he cannot explain, a disinclination to fly. He feels 'dud', 'sick of the air', 'hates the sight of a machine'. Sleep may be bad or he may often experience nightmares. He is generally 'flying-tired', and in this connexion the loss of expiratory force is illuminating.

Although a loss of power is perhaps first associated with the respiratory mechanism, especially with the abdominal muscles concerned in expiration, there is frequently at this stage a loss of muscular tone generally.

When the stage of breakdown is reached, the subject has to give up flying altogether, and at this stage the cardio-vascular psychic or nervous symptoms become more marked, as does also the general loss of muscular tone.

In regard to the voluntary system, this loss is shown by a lessened force of the cheek and mouth muscles; in respect of the involuntary system by the loss of tone in the stomach and bladder walls.

At this stage it is difficult to forecast whether a case will be regarded as primarily nervous, e. g. nervous breakdown, nervous exhaustion, neurasthenia, and be passed to the neurologist, psychologist, or as primarily cardio-vascular (cardio-vascular debility) and passed to the physician.

It is suggested that an abnormal state of the bulbar centres with defective respiratory ventilation may be found in cases of stress other than flying. Professor Dreyer [1] has recently shown that the vital capacity of a subject can be accurately calculated from the weight, stem length, and chest circumference of the individual. The exact diminution of the vital capacity in a subject can therefore be accurately ascertained, and it is probable that this measurement as well as the test for expiratory force and the test of sustaining 40 mm. Hg by blowing would indicate the degree of stress in subjects after a long and trying period in the trenches. This has been found to be true in several cases examined. It would be of interest, also, to apply the test among subjects liable to suffer from industrial fatigue, such as munition workers.

[1] Dreyer, loc. cit. (p. 95).

H. Conclusions.

1. The measurement of the vital capacity is important in candidates for aviation and in pilots. Its adequacy should be calculated from the formulae put forward by Dreyer. The vital capacity is greatly diminished in cases of flying fatigue. In its measurement the subject sits opposite the spirometer, the dial being so placed that he cannot see the readings. Movement of neck, chest, and abdomen must be unhampered. He is directed to fill his lungs to the fullest extent and then to expire as completely as possible through the meter. Five readings should be taken.

2. Other simple tests are described which it is believed will prove valuable in 'assessing' flying stress and also in determining the fitness of candidates for flying. These tests should be used in conjunction with the points found in the medical examination.

3. The test for breath-holding capacity is as follows:

The subject is asked to expire as deeply as possible (preferably audibly), and then to fill the lungs fully (but not to absolute distension), and to hold the breath with the nose clipped or held. The reason for the audible expiration is that it has been observed that some subjects suffering from stress have lost the power of expiring fully, and a marked shortening of time taken to expire, as fully as possible, may afford an indication of such loss of power. The time during which the breath is held is noted, and the subject is then asked the reason for giving up. This should be recorded. The significance of the test and the time that it is expected must not be communicated, and on no account may any one time himself.

The subject should be asked the reason for ceasing. Normally, an answer such as 'I had to give up', 'I felt I should burst', 'I wanted to breathe' is given. Subjects suffering from marked disability at altitudes almost invariably return an abnormal answer, e.g. 'I became giddy or dizzy', 'Things went blurred'. 'The blood rushed to my temples', 'I began to feel squeamish'. Where the answer is deemed not to be normal the subject's own words should be given.

The average time the breath is held by the normal fit pilot is 60 seconds, the minimum time being 45 seconds. Generally speaking, a man who does not hold his breath 45 seconds should not be admitted as a pilot. As a matter of experience it will be found that very nearly all such cases will be rejected on medical grounds, apart from this test. The test is believed to afford indication of

(*a*) The stability of the respiratory centre, and indirectly, of the nervous system generally;

(*b*) The likelihood (when the time is short and an abnormal answer is given) of the subject suffering from oxygen want at altitudes;

(*c*) Resolution to 'carry on' under conditions of stress.

4. The test for Expiratory Force is carried out in the following manner:

The applicant or airman is asked to hold his cheeks with the thumb and forefinger of the left hand, and steadily blow the mercury

column of the standard U-tube up as high as possible with the scale turned away. Several mouth-pieces should be kept in disinfectant and carefully cleaned for each subject. On no account must the applicant or airman be allowed to swing the mercury up violently, and in all cases the height of any initial swing is to be disregarded. The reason for holding the cheeks is that it has been found that in some cases the mercury may be forced up to abnormal heights by the action of the cheek muscles. The number of mm. Hg blown is recorded. The examinee is then asked to repeat the performance while looking at the column. The resolute subject may, under these conditions, considerably pass the effort which he did not see, in this way affording some indication of his mental make-up. On the other hand, a subject who is not trying may give very discrepant readings. With the manometer again turned away, he may, by encouragement, be made to surpass his previous efforts, but when, after trying again whilst looking at the manometer scale, he will not surpass if he is not really trying the previous effort which he saw.

The average for normal individuals is about 105 mm. Hg. When under 80 mm. Hg it suggests that the subject will probably be incapable of sustained effort in routine aerial work, and should probably be rejected. The test, however, should be taken in conjunction with the results of the rest of the examination.

5. The test of sustaining 40 mm. Hg with the breath held is performed as follows:

The subject is asked to empty the lungs, fill up, blow the mercury to the height of 40 mm., and hold it there *without breathing* for as long as possible, preferably with the nose clipped. The average normal time in the large number of cases tested is 50 seconds. Below 40 seconds is unsatisfactory, and indicates that probably the subject is fit only for limited flying or in need of a rest. This can be assessed from the other points noted during the examination. Pilots broken down from stress of service have an average of about 25 seconds.

6. A valuable adjunct to the test is the behaviour of the pulse during the time the mercury is being sustained. This is counted during each five seconds that the mercury is sustained. Starting at the 5th second in the normal individual, there is generally a steady slow rise in the rate of the pulse, or a fairly marked rise, which is sustained most of the time. For example, the pulse rate may rise gradually from 72 to 96 or 108, according to the time the breath is held, or the pulse may rise almost at once from 72 to 98 or 108, and be sustained there. A large rise in rate, e. g. from 72 to 132 or 144, is unsatisfactory. In cases of flying stress the characteristic response is for the pulse to jump quickly up during the 5th to the 10th or 15th second, and then to fall away in rate to normal or even below normal. A bad response is as follows:

> Normal at start, 84;
> 5th–10th second, 144, often almost imperceptible;
> Falling away (say 20–25th second) to 72 or even 60.

7. The above tests show the necessity of a firm-toned abdominal wall in the flying officer. This is of importance for the maintenance

of efficient respiratory ventilation, and also to prevent any tendency to the pooling of blood in the abdomen.

8. The fact that the first indications of 'fatigue' are associated with the loss of power to sustain 40 mm. Hg. and also frequently with a diminished capacity to hold the breath, suggests the tentative explanation that the first stage in the onset of flying fatigue is due in many cases to an altered tone of the respiratory centre. This leads later to a diminution of the vital capacity, supplemental air, and loss of expiratory force. Defective respiratory ventilation then brings about lessened oxygenation of the body, which reacts upon other systems, particularly upon the circulatory and nervous systems.

8.—TEMPERAMENT AND SERVICE FLYING

BY

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The object of this paper is first to draw attention to certain aspects of service flying with which medical officers in the Field are confronted every day, and secondly to discuss the significance of certain of the tests introduced by Lieut.-Colonel Flack and the results obtained by their employment (*vide* No. 3 of this volume).

A pupil under instruction is chiefly of interest from the point of view of his capacity as a pilot (i. e. a chauffeur), whereas in the Field the fully-fledged flying officer absorbs our attention in his capacity as a combatant; in fact, it cannot be too often insisted that an aeroplane is *par excellence* a gun mounting, designed to inflict losses on the enemy in his own territory. It therefore follows that the flying temperament, i. e. the temperament for flying *per se*, is of little importance in the Field, since those devoid of it do not, with few exceptions, reach the active service stage. The temperament for fighting and for combatant service in general is, on the other hand, a matter demanding our close attention.

It is not within the ability of the writer to attempt any close analysis of what is known as Temperament. Suffice it to say that it is intimately bound up with Character, both hereditary and acquired, and plays a large part in determining an individual's conduct and manner of life. The War has created a situation in which hundreds of thousands of men have been required and expected to expose themselves to discomforts and dangers undreamt of four years ago, and it is mainly owing to fundamental differences in temperament that the requirements have not been, and never can be, equally fulfilled. Equality of Service is a most desirable object to aim at; it is none the less desirable to recognize that it is impossible of attainment. It accordingly happens that we constantly meet with individuals who are incapable of sustaining for an average period the effort, physical and mental, which service as a combatant demands. This is true of all branches of the Service, but each branch demonstrates its own peculiarities. The fundamental peculiarity of combatant service in the air lies not so much in the fact that the air is not the natural element of Man, but rather in the circumstance that flying demands and encourages a degree of individualism unknown in any other branch of the Service. Formation flying, no matter to what extent it is developed, although it can diminish, can never entirely abolish, this outstanding peculiarity, which is a hall-mark of the Air Service.

These considerations attain considerable practical importance in dealing with individuals who, on their own showing or in the opinion of their Commanding Officers, are temperamentally unsuited for service flying. Such an individual may not only be fond of flying, but may even be a skilled pilot. Even so, is it proper to turn him

into an instructor, a test pilot, or a ferry pilot? As an instructor, with but few exceptions, clearly No, lest his temperament infect his pupils; for it must be remembered that he will be instructing others to fly in order that they may eventually fight. As a test or ferry pilot? In the opinion of the writer the answer depends entirely on the degree of physical fitness of the individual in question. If he is not fit for combatant service on the ground he will be clearly most usefully and economically employed in non-combatant service in the air. If fit on the ground, however, the decision rests entirely with the executive authorities, who may decide to transfer him to the infantry. It may be asked, Why if unfit for temperamental reasons for combatant service in the air can an individual be considered likely to prove of value as a combatant in the trenches? The answer has already been discussed. On the ground fewer calls will be made on his individuality, and more opportunities will be afforded for gaining confidence in himself from intimate comradeship with those of tougher calibre, with the result that he may eventually discover himself, and even acquire the art and spirit of leadership.

The term temperamental unfitness has crept into use largely for want of a better one, and its precise meaning is a source of frequent discussion and considerable perplexity. It might be said, for example, that a successful pilot suffering from stress of service was temperamentally unfit. This view is incorrect; he is unfit only in so far as his temperament, i.e. his outlook on things and powers of resistance, has undergone modification as the result of fatigue, whereas he is clearly not unfit by virtue of his temperament regarded as part of his normal ego. Youth and immaturity are also factors to be taken into consideration (*vide* Table VII, case 8).

It is now recognized that Temperament is a matter for study by executive and medical officers in conjunction, since the line which divides the physically from the temperamentally unfit is, as will be presently pointed out, as imaginary as the equator.

Before proceeding to analyse the results of the physical examination of different categories of pilots, it will be as well to say a few words on the methods employed. Nearly all the cases have been examined by Captain C. D. H. Corbett and Captain H. C. Bazett, M.C., to whose unfailing industry I should like to pay a grateful, if wholly inadequate, tribute.

Every patient brings with him a brief history of his case made out by his Wing Medical Officer, and in most instances a few lines from his Squadron or Flight Commander. He is examined the morning after admission, and is not allowed out of bed until his turn for examination comes. He then walks into the examining room in dressing-gown and slippers, and sits down.

The routine examination is conducted as follows:

1. Past medical history and military history, i.e. previous service abroad, whether combatant or not, date of joining the Air Service, by whom medically examined, date of wings, date of qualifying as observer, number of hours flown in England and on active service, type of work, &c.
2. Age, height, weight.

3. Present history leading up to his admission to hospital.

By this time the examiner should not only have obtained some valuable information, but should also have gained the confidence of his patient, and all nervous excitement due to the immediate surroundings should be in abeyance.

The physical examination is then conducted as follows :

4. The pulse is counted over one minute and recorded every 15 seconds.
   a, sitting ; *b*, standing ; *c*, after exercise, which consists in the patient raising himself slowly and in the upright position five times on to a chair.
5. Examination of the heart and lungs.
6. Determination of the systolic and diastolic blood-pressures by the auscultatory method.
7. Expiratory force, as determined by the manometer.
8. Time in seconds of holding up the mercury to 40 mm., and the behaviour of the pulse during the test.
9. Respiratory rate at rest.
10. Vital capacity, and tidal air.
11. Ventilation per minute at rest.
12. Examination of the abdomen and abdominal wall.
13. Condition of the reflexes ; presence or absence of tremor.
14. Condition of the tympanic membranes.
15. Presence or absence of Eustachian obstruction.
16. Visual acuity.

In addition, the writer makes it a practice of having private consultations, lasting five to ten minutes, with selected patients. These are made as unofficial as possible, and frankness of utterance is encouraged on both sides.

In the following tables the results only of the pulse-rates, blood-pressures, expiratory force, and sustaining the mercury test are recorded. As regards the two former no attempt at close analysis is made, still less is any effort made to discuss the results from the point of view of the mechanical efficiency of the cardio-vascular system. It has been shown by Starling and his co-workers by the use of the heart-lung preparation that the heart is capable of responding within wide limits to changes in the mechanical demands made upon it, so that ' it is difficult to imagine a more perfectly regulated machine than the heart '. How wide these limits can be is demonstrated in the following tables, where high and low blood-pressures are combined with fast and slow pulses in a seemingly random manner.

Flack has tentatively put forward the hypothesis that the first stage in the onset of flying stress, especially in flying at high altitudes, is an altered condition of tone of the respiratory centre of such a kind that the regulation of respiration is no longer normal, and that this alteration is demonstrable by the ' sustaining the mercury test '. In view of this hypothesis it has been thought advisable to give the results obtained in a series of pilots and observers who have been recommended by their commanding officers for transfer to England for a rest on account of fatigue. The results will be found in Table I.[1]

TABLE I. PILOTS AND OBSERVERS TRANSFERRED TO HOME ESTABLISHMENT FOR A REST

(a) BRISTOL FIGHTER AND D.H. PILOTS AND OBSERVERS

Serial Number, Rank, and Initials.	*Age.*	*Remarks.*	*Months since posted Overseas.*	*No. of Hours War Flying.*	*Expectoration c.c. per Hg.*	*Time in Seconds of Sustaining 40 mm. Hg by Blowing*	*Blood Pressure.*	PULSE. *Sitting.*	*Standing.*	*Exercise.*	*Remarks*
1. Capt. R. N. C. A., M.C.	21	Long spell overseas. 1916-17. Pilot.	2	420 (1916-17)' 80 (1918)	140	40	105/70	72	90	90	Pain in ear due to Eustachian obstruction. Very hard work lately Feels very tired. Returned one month later. Doing very well.
2. Capt. C. P. O. B., D.S.C.	29	Very experienced pilot Long bombing.	18	300	90	42	102/67	73	102	109	Not slept well for one year. Feels done up. Headache on landing. Short of breath on ground.
3. 2nd Lt. W. D. B.	26	Pilot.	6	170			125/75	74	83	97	Headache on landing. Feels slack and tired. Loss of interest.
4. Capt. B. E. B., D.S.O., M.C.	21	550 hours as instructor. Has done much long-distance running	9	450 (1916) 300	180	57	120/85	80	78	85	Never affected by altitude until recently. Now severe landing headache. Otherwise fit. Lost some of his dash.
5. Capt. D. G. C., M.C.	22	Pilot. Flight Commander.	7	240	120	48	136/85	71	85	94	Not affected by altitude, but now tired after flying. Losing his dash.
6. Lt. H. G. C., M.C.	20	Observer. Non-smoker Teetotaller.	5	144	190	48	135/95	54	64	67	Feels fit and ready to learn to fly.

7. Lt. T. G. J.	20	Pilot.	7	150	90	48	115	90	88 103 107	Fainted recently at 13,000 feet. Feels tired and washed out.
8. Lt. S. H. P. M.	21	Pilot.	6½	160	100	47	135	98	76 82 99	Not as happy over the lines as he used to be.
9. H. F. M.	20	Pilot.	6	120	165	59	112	75	77 89 101	Feels tired; cannot stand heights nearly as well as he could.
10. Lt. L. H. P.	23	Pilot.	6	160	145	61	108	68	63 71 71	Very heavy work lately, and is feeling the effects.
11. R. S.	22	N.C.O. Observer;	12	150	120	40	140	70	82 89 100	'Wind up' one month—quite fit before. Doesn't want to learn to fly at present.
12. Capt. E. I. S. J.	20	Pilot. Flight Commander.	7	215	72	30	112	70	63 73 80	Latterly had to force himself into the air. Cannot stand heights now, gets so short of breath.
13. 2nd Lt. A. T. H. T.	19	Observer. Rejected by C.B. as pilot	5	100	180	45	120	75	76 92 99	A bit shaky lately. Nothing. Very keen to learn to fly. Used to be long-distance runner.
14. Capt. V. S. W.	21	Pilot. Flight Commander.	15	160	90	48	134	72	80 102 120	Hopelessly sick.
15. Lt. C. D. T.	21	Pilot.	3	150	100	46	135	80	72 83 95	Very hard work lately. Looks and feels tired out. Headache on landing.
16. Capt. L. A. P., M.C.	24	Pilot. Flight Commander.	9	234	150	35	110	75	63 69 81	Feeling fit except for dental trouble. Still unaffected in attitude.

TABLE I. PILOTS AND OBSERVERS TRANSFERRED TO HOME ESTABLISHMENT FOR A REST

(*a*) BRISTOL FIGHTER AND D.H. PILOTS AND OBSERVERS (*continued*)

Serial Number, Rank, and Initials.	*Age.*	*Remarks*	*Months since posted Overseas.*	*No. of Hours War Flying.*	*Expiratory Force in mm. Hg.*	*Time in Seconds of Sustaining 40 mm. Hg by Blowing.*	*Blood Pressure.*	PULSE. *Sitting.* *Standing.* *Exercise.*	*Remarks.*
17. Lt. E. L.	21	Pilot. Teetotaller.	7½	260	110	43	125 70	63 79 99	Worried by A.A. shells, which he never used to be. Feels slack.
18. 2nd Lt. G. D.	26	Observer. Rejected by C.B. as pilot.	8	140	198	60	140 100	83 87 90	Magnificent physique. Sick of observing. Wants to learn to fly.
19. Lt. C. D. P.	21	Observer.	7	160	90	65	118 74	51 76 87	Highly strung. Sleeping in air lately. Feels fairly fit, but stale.
20. Lt. S. A. O., M.C.	27	Pilot.	7	180	150	82	114 72	70 84 89	Entirely unaffected by altitude. Tired and stale. Lost keenness.
				AVERAGE	130·5	49·7	121, 74	71 84 93	

(*b*) SCOUT PILOTS

1. Capt. J. O. A., D.S.O., M.C.	21	200 hours as an instructor. Seen a lot of service.	1	600 (1915–17) 40	70	60	122 80	63 89 91	Not fit when he came out. Sleeping badly two years. Depressed, muddle-headed. Feels strain of war flying.
2. Capt. F. B.	23	200 hours H.D. Flight Commander.	3	300 obs 200 (1917) 90	90	40	135, 80	81 89 97	Not fit when he came out. Vomiting in air, getting worse. Headache, general fatigue. One month later returned to night bombers. Since awarded D.F.C.

3. Capt. L. D. B.	29	Flight Commander.	9	200 obs. (1916) 275	104	46	122/78	60 68 80	Tired-reaction after flying. Much low straing lately. 6 Dioptres of Myopia in each eye.
4. Capt. H. H. B., M.C.	20	Flight Commander. Excitable type.	4	170 (1917) 150	86	27	130/72	69 77 86	Low straing lately. Absolutely worn out. Dreams every night that he is taken prisoner.
5. Lt. C. F. C.	28		5	125	82	61	95/70	61 70 71	Nearly fainted in air short while ago. Otherwise feels fit.
6. Capt. H. F. S. D., M.C.	23	Flight Commander.	8	250	130	60	106/66	63 89 91	Very tired—chiefly result of low straing.
7. Capt. S. E., D.S.C.	25	Flight Commander.	24	450	120	43	115/90	68 97 109	Feeling done in last month. Broke down yesterday after patrol.
8. Capt. O. H., M.C.	25	Flight Commander. 3 times wounded in infantry.	6	190	90	60	135/90	59 75 81	Sleeping badly lately. Anginal attack in air recently. Killed flying in England 19.8.18.
9. Lt. R. G. H., M.C.	20		8	250	112	57	120/90	83 90 104	Feels fit but gets praecordial pain at high altitudes and progressively tired after landing.
10. Lt. T. F. L.	26	a/Flight Commander.	7	150	90	40	135/95	86 94 98	Not sleeping well. Feels 'done up'. Kept going on C.H. OH
11. Capt. K. M. L., M.C.	21	Flight Commander.	7	150 (1916) 200	125	42	104/60	61 69 76	Tired one month. Loss of interest Persistent headache.
12. Capt. G. E. H. McE., M.C., D.F.C.	24	Flight Commander. Asthmatical, some emphysema.	8	215	110	45	115/82	66 79 80	Very tired—low straing. Returned two months later and did magnificently. Reported missing 1.8.18.

TABLE I. PILOTS AND OBSERVERS TRANSFERRED TO HOME ESTABLISHMENT FOR A REST

(*b*) SCOUT PILOTS (*continued*)

Serial Number, Rank, and Initials.	*Age*	*Remarks.*	*Months since posted Overseas.*	*No. of Hours War Flying.*	*Expiratory Force in mm. Hg.*	*Time in Seconds of Sustaining 40 mm. Hg by Blowing.*	*Blood Pressure.*	PULSE. *Sitting.* *Standing.* *Exercise.*	*Remarks.*
13. Capt. H. H. R., M.C.	21	230 hours testing Flight Commander	4	140	130	60	140/85	67 83 86	Drowsy in the air. Getting jumpy and losing confidence. Recommended for Australian leave.
14. Lt. C. L. S.	18	Very small physique.	6	220	120	25	115/90	94 102 117	Excitable type. Unaffected by altitude. Feels fit.
15. Lt. H. W. S.	21	Observer (1916-17).	5	160 obs. 120	120	40	120/76	83 104 102	Nearly fainted in air two days ago Feels tired and slack.
16. Capt. W. B. T.	25	Flight Commander.	5	170	150	45	140/98	62 85 94	Getting jumpy. Goes to sleep in the air and feels incapable of looking after his flight.
17. 2nd Lt. C. T. T.	19	100 hours instructing.	7	250	120	63	102/62	63 77 84	Headache last three weeks. Otherwise fit. Looks tired.
18. Lt. H. S. W.	19	Diminutive physique.	8	170	98	22	140/85	92 104 110	Badly shot about lately. Has lost confidence.
19. Lt. P. E. W.	29		9	200	120	64	130/90	71 86 99	Been making bad landings. Feels thoroughly tired. Nightmares.
20. Capt. T. E. W.	26	Flight Commander. Observer (1916-17).	7	185 obs. 195	85	55	120/80	54 64 76	Never sick since war began. Latterly been less successful in air. Feels fit.

21. Lt. H. L.	19		4½	160	120	45	115/75	84 100 106	Lost his dash. Looks and feels tired.
22. Lt. P. W.	19		5	173	120	35	140/100	68 72 84	Not flying so well lately. Lost dash and energy.
23. Capt. A. W. C., D.S.C.	24	Flight Commander.	15	500	100	60	122/80	64 78 81	Very stale—lost the offensive spirit.
24. Lt. K. G. P. H	19		6	170	170	60	138/70	—	Crashed 14 days ago—unconscious three days. Now feels 'full out'.
25. Capt. C. O. R.	22	Flight Commander.	7	200	160	75	96/58	60 70 75	Feeling strained. Sleepy above 14,000 feet. Praecordial pain on ground.
26. Capt. G. C. M.	34	Flight Commander.	5	150	130	43	110/60	74 79 91	Worried about defective vision in one eye when leading patrols. Otherwise fit.
				AVERAGE	1085	47·2	121/80	70 83 90	

(c) ARTILLERY PILOTS AND OBSERVERS

1 Lt. W. A. M.	20	Observer.	6½	180	205	53	122/88	68 79 91	Recent perforation of drum. Feels fit. Very keen to become pilot.
2 Lt. J. E. A.	23	Pilot.	6	150	100	31	110/75	65 83 96	Bad landings last ten days. Nearly fainted in air. Some loss of confidence.

TABLE I. PILOTS AND OBSERVERS TRANSFERRED TO HOME ESTABLISHMENT FOR A REST

(c) ARTILLERY PILOTS AND OBSERVERS (*continued*)

Serial Number, Rank, and Initials.	*Age.*	*Remarks.*	*Months since posted Overseas.*	*No. of Hours War Flying.*	*Expiratory Force in mm. Hg.*	*Time in Seconds of Sustaining 40 mm. Hg by Blowing.*	*Blood Pressure.*	Pulse. *Sitting. Standing. Exercise.*	*Remarks.*
3. Lt. W. J. A.	21	Observer in 1916–17.	5	200 obs. 200	105	35	140/85	66 88 99	Fainted at 6,000 feet six weeks ago. Headache. Feels he has had enough.
4. Lt. C. E. A.	20	Pilot.	9	200	180	30	142/105	68 86 100	Not the least bit tired or strained.
5. Lt. H. A. B.	21	Pilot.	8½	200	170	48	140/95	61 68 83	Lost interest in his work. Feels well in himself.
6. Lt. S. H. B.	27	Observer.	4	190	90	40	105/70	73 87 90	Praecordial pain three weeks. Tired—has lost confidence.
7. Lt. W. M. E.	21	Pilot.	8	160	170	55	115/75	66 92 95	Completely tired out. No energy left.
8. Capt. J. S. G., M.C.	23	Flight Commander.	13	330	100	32	130/95	65 82 104	Loss of confidence in air one month. Restless.
9. Lt. R. C. H.	24	Observer.	8	210	108	70	124/75	73 78 73	Restless. Eyes tired. standard of work has fallen off.
10. 2nd Lt. L. A. L.	19	Pilot.	9	340	100	35	142/60	72 80 90	Feeling strain. Getting jumpy and irritable. No energy. Sleeping badly.

11. Capt. H.S.M.S., M.C.	22	Flight Commander.	12	260	110	70	130 70	72 85 88	Feels perfectly fit.
12. Lt. A. F. McG., M.C.	19	Pilot.	11	315	100	33	118 78	88 100 110	Tired seven weeks. Restless and unsociable. Dyspnœa above 6,000 feet.
13. Capt. J. P.	22	Flight Commander.	10½	400	102	34	115 85	70 82 93	Jumpy one month. Cannot bear to watch machines landing.
14. Lt. G. B. P.	19	Observer.	6	180	150	50	125 72	84 99 106	Fed up with observing.
15. Lt. J. J. Q., M.C.	21	Pilot.	6	180	90	32	116 80	70 87 101	No energy. Restless. Sleeping badly. Talking in sleep.
16. Lt. L. V. S.	19	Observer.	6	135	180	40	140 100	81 88 100	Not up to the mark lately. Sleeping poorly. Tired after long flights.
17. Lt. D. W. S.	19	Pilot.	9½	380	115	38	132 72	—	Feels he could do another two months.
18. Capt. R. D. S., M.C.	26	Flight Commander. Teetotaller.	10	350	110	35	—	72 80 93	Tired out. Sleeping badly lately. Bronchitis.
19. Lt. D. S. T.	24	Pilot.	9	400	90	48	120 75	74 80 94	Battery knocked about flying. Otherwise feels fit.
20. Lt. J. T.	24	Observer.	4	200	100	48	—	63 71 76	Badly crashed two months ago. Not [illegible]

TABLE I. PILOTS AND OBSERVERS TRANSFERRED TO HOME ESTABLISHMENT FOR A REST

(*c*) ARTILLERY PILOT AND OBSERVERS (*continued*)

Serial Number, Rank, and Initials.	*Age.*	*Remarks.*	*Months since posted Overseas*	*No. of Hours War Flying.*	*Expiratory Force in mm. Hg.*	*Time in Seconds of Sustaining 40 mm. Hg by Blowing.*	*Blood Pressure.*	PULSE. *Sitting.*	*Standing.*	*Exercise.*	*Remarks.*
21. Lt. J. H. U., M.C.	29	Observer. Rejected by C.B. as Observer.	11	215	118	33	110/70	70	83	99	Feels very fit. Began to get tired five months ago, but was restored by leave.
22. Lt. S. G. W.	27	Observer	5	146	85	55	—	81	94	115	Sick in air lately. Sleeping badly. Tired and run down.
23. Capt. F. F., M.C.	22	Flight Commander 400 hours instructing.	13	600	115	45	120/78	65	82	84	Everything is an effort. Irritable and unsociable. Hates his work.
24. Lt. H. S. W.	24	Pilot.	3	150	70	35	—	79	85	91	Heavy work lately. Low straling. Feels rattled.
				AVERAGE	119·3	43·5	125/80	71	84	94	

(*d*) NIGHT-FLYING PILOTS AND OBSERVERS

1. Lt. T. H. D. S.	19	Observer.	5	100	110	45	110/60	68	85	96	Many forced landings lately. Sleeping badly. Tired. Very keen to learn to fly.
2. Lt. M. S.	26	Observer.	6	104	120	65	120/90	58	67	88	Headaches lately. Keen to learn to fly.

3. Capt. A. L. C.	27	Flight Commander. 200 hours H.D.	2	60	125	55	148/100	108 123 147	No leave for 18 months. 'Flu' three weeks ago. Now D.A.H
4. Lt. L. D. P.	19	Observer.	3	70	72	47	120/70	95 110 115	Numerous forced landings lately Pilot killed. Restless and sleepless. Very jumpy.
5. Capt. P. G. S.	23	Flight Commander.	3	400 obs. (1916) 120	70	37	136/95	52 60 72	Irritable and restless. Never used to be like this.
6. Lt. E. R. H. B.	26	Pilot. a/Flight Commander.	4	118	120	50	125/95	65 82 101	Eight forced landings in 14 days Very tired. Returned one month later. Did 50 hours more, then to H.E with exp. force 90 and fatigue test 42.
7. Lt. A. H. G. D.	22	Pilot.	6	150	90	50	120/65	66 76 79	Feels as fit as ever.
8. Capt. W. H. T.	26	Flight Commander. 200 hours H.D. 100 hours instructing.	2	425 obs. (1916-17) 170 (1917) 60	70	46	124/90	94 106 118	Worked to death never had any decent leave. Wants to jump out of machine.
9. Lt. S. C. H.	25	Pilot.	6	100	80	30	112/60	80 88 96	Three forced landings with bombs on board Lost confidence. Depressed.
10. Capt. H. M. C.	27	Flight Commander. 500 hours H.D.	8	100	80	30	118/70	51 56 63	Very tired and apprehensive.
11. Lt. B. R. S. L.	21	Pilot.	2	190 obs. (1917) 30	70	30	125/75	80 93 105	No leave for a year. Very tired headaches.
12. Lt. A. L. S.	25	Pilot. 50 hours H.D.	7	90	100	48	122/74	68 77 85	Headaches. Stale. Getting in an unsteady
13. Lt. T. T., D.S.C.	19	Observer.	12	200	100	35	130/90	78 100 107	Excitable type. Very tired.

TABLE I. PILOTS AND OBSERVERS TRANSFERRED TO HOME ESTABLISHMENT FOR A REST

(*d*) NIGHT-FLYING PILOTS AND OBSERVERS (*continued*)

Serial Number, Rank, and Initials.	*Age*	*Remarks.*	*Months since posted Overseas.*	*No. of Hours War Flying.*	*Expiratory Force in mm. Hg.*	*Time in Seconds of Sustained 40 mm. Hg by Blowing.*	*Blood Pressure.*	PULSE. *Sitting.*	*Standing.*	*Exercise.*	*Remarks*
14. 2nd Lt. M. M. T.	32	Observer.	5	40	125	52	127/78	73	104	112	Heavy work last three weeks. Getting jumpy. Thinks he is too old.
15. Lt. J. P.	27	Observer.		85	110	50	134/75	95	102	110	Blind in one eye—very good observer. Tired but keen to learn to fly.
16. Capt. P. W. R	22	Flight Commander.	7	100	110	55	122/95	72	81	92	Not sleeping too well. Lost some of his keenness.
17. 2nd Lt. C. A. McC.	19	Pilot. 40 hours H.D	6	100	130	40	123/90	87	96	114	Shaky last two months and has palpitation on exertion. D.A.H.
18. Lt. E. W. C.	29	Pilot. 40 hours H.D.	6	100	140	43	110/70	80	89	91	Lived in hot climates. Has had malaria, typhoid, and dysentery. Feels the cold. Bronchitis. Otherwise fit.
19. Capt. M.G.F.R.	25	Flight Commander 400 hours H.D.	5	70	100	38	105/55	66	77	83	Forced landings lately. Tired and lost confidence.
20. Lt. W. R.	26	Observer.	6	100	135	55	112/75	68	89	109	Feeling stale but anxious to learn to fly.
21. Lt. W. F.	24	Observer.	7	100	120	59	135/75	84	97	106	A little run down but nothing to speak of.
				AVERAGE	103·6	45·7	127/78	76	89	100	

As it is reasonable to assume that the respiratory centre is likely to be more affected in those who fly high rather than those who fly low, sub-classifications have been made into (*a*) Bristol Fighter and D.H. pilots, (*b*) Scout pilots, (*c*) Artillery pilots, (*d*) Night pilots. None of the individuals had used oxygen in the air.

TABLE II

Subject.	*No. of cases examined.*	*Expiratory force in mm. Hg.*	*Seconds of sustaining 40 mm. Hg.*	*Blood pressure in mm. Hg.*	*Sitting pulse.*	*Standing pulse.*	*Exercise pulse.*
I. All pilots and observers on transfer to H.E. for a rest.	91	116·6	46·7	123·78	72	85	95
(*a*) Bristol Fighter and D.H.	20	130·5	49·7	121·74	71	84	93
(*b*) Scouts.	26	108·5	47·2	121·79	70	83	90
(*c*) Artillery.	24	119·3	43·5	125/80	71	84	94
(*d*) Night flying.	21	103·6	45·7	127/78	76	89	100
II. Fit instructors	22	112	52	—	—	—	—
III. Pilots returned for rest.	17	95	40	—	—	—	—
IV. Pilots taken off flying through stress.	27	74	25	—	—	—	—

It will be seen that the Bristol Fighter and D. H. pilots are the best in the series in both the manometer tests, while scouts are better than the artillery series in the 'fatigue' test, and not so good in the expiratory force test.

Compared with the results obtained by Flack (*vide* No. 7 of this volume, Table XIII. p. 119), as the table given above shows (Table II), the home establishment series is only slightly below the standard of fit instructors and home defence pilots on the fatigue test, and as good if not better on the expiratory force test. They are immeasurably superior to the series of pilots taken off flying through stress, and markedly superior to pilots 'returned for rest'. From this last comparison we are perhaps justified in hoping that flying officers are now withdrawn from the line before their powers of recuperation have undergone any permanent diminution.

The above results do not warrant the assumption that high flying *per se*, at any rate at the stage at which pilots and observers are nowadays withdrawn from the line, produces an altered tone of the respiratory centre of such a character as to be demonstrable by the manometer tests. It should, however, be remembered that the individuals included in Table I are to a certain extent representatives of the fittest to survive. In this connexion it is not proposed to push the comparison between Bristol Fighter pilots (average 16,000 feet) and night-bombers (average 3,000 feet). It is the general opinion of most wing medical officers that the pilot who has been employed on night work compares unfavourably as regards

TABLE III. CONCUSSION CASES

Serial Number, Rank, and Initials.	*Age.*	*Remarks*	*Hours flown on Active Service*	*Expiratory Force in mm. Hg.*	*Seconds for Sustaining 40 mm. Hg.*	*Blood Pressure in mm. Hg.*	PULSE. *Sitting. Standing. Exercise.*	*Disposal.*	*Remarks*
1. Lt. H. V. B.	19	Bristol Fighter Pilot.	22	65	19	100/64	83 95 112	England.	Brought down in No Man's Land. Unconscious ½ hour. Much shaken.
2. Capt. P. B., D.S.C.	22	Handley Page Observer.	120	70	15	115/70	58 68 72	England.	Never able to fly above 10,000 feet. Week ago shot down in sea. Dazed. Pilot drowned. Shaken.
3. 2nd Lt. J. Y. B.	27	D.H. 4. Observer.	40	130	32	138/84	85 88 102	England.	Two crashes last week. Knocked out for few seconds. Hospital since. Very shaky.
4. Lt. R. B. D.	19	Scout Pilot.	20	120	52	125/72	71 87 96	Sick leave.	Crashed taking off. Dazed not unconscious. Now lost confidence. ? Temperamentally unfit. Did not return.
5. 2nd Lt. F. G.	21	Artillery Pilot.	45	100	28	125/80	90 101 101	England.	Crashed—unconscious five minutes. Headache and lassitude ever since.
6. Major G. P. H.	26	Scout Pilot.	60	140	40	120/75	74 80 87	England.	Crashed one month ago unconscious five minutes. Headache ever since. Giddy in air and on ground. Insomnia.
7. 2nd Lt. F. A. W. M.	21	D.H. 4. Pilot.	75	75	33	128/68	71 78 83	England.	Machine collided with his on aerodrome. Unconscious ten minutes. Headache and syncopal attacks ever since.

8. 2nd Lt. C. M.	21	Scout Pilot.	140	115	39	120 75	58 68 66	Sick leave.	Two days ago shot down. Unconscious ten minutes. Headache and lassitude. Rapid improvement. Since killed in collision over lines.
9. Lt. H. H. P.	26	Artillery Pilot.	110	120	42	145/115	72 83 92	Sick leave.	Machine caught fire—crashed. Remembers nothing about it. Headache since. Shaken. Returned and did good work for seven weeks.
10. Lt. J. E. S.	19	Artillery Pilot	45	80	55	140/88	99 113 125	Sick leave.	Crashed 12 days ago. Unconscious ½ hour. Headache and loss of energy. Improved. Doing very good work since return.
11. Lt. S. T. T.	18	Scout Pilot.	2	90	36	125 90	76 87 95	England.	Crashed—unconscious three hours. Now feels fit. To have further instruction in flying. Loss of confidence.
12. Lt. L. M. T.	24	Bristol Fighter Observer.	150	130	45	142/110	93 99 106	Sick leave.	Crashed two weeks ago—unconscious 90 minutes. Now feels fit. Did well on return.
13. Capt. H. A. W.	21	Scout Flight Commander.	80	110	50	130 90		Duty.	Crashed six days ago—unconscious 15 minutes. Confused 12 hours. Now full out. Since brought down several E.A. Awarded D.F.C. and D.S.O.
14. Lt. C. F. P. H.	19	Scout Pilot.	2	80	25	145 100	96 101 113	England.	Collided in air with Flight Commander, who was killed. Unconscious two minutes. Insomnia and headaches since.
15. Lt. C. H. C	23	Scout Pilot.	65	160	45	120 70	62 78 88	Sick leave.	Crashed week ago. Unconscious 24 hours. Headache two days. Now feels fit. Did well on return.
16. Lt. T. L. B.	20	Artillery Pilot.	130	100	40	135 94	67 76 83	Sick leave.	Shot down, crashed, stunned. Stunned ten minutes. Headache since. Did very good work on return. Awarded D.F.C.

TABLE III. CONCUSSION CASES *(continued)*

Serial Number, Rank, and Initials.	*Age.*	*Remarks.*	*Hours flown on Active Service.*	*Expiratory Force in mm. Hg.*	*Seconds for sustaining 40 mm. Hg*	*Blood Pressure in mm. Hg.*	PULSE. *Sitting* / *Standing.* / *Exercise.*	*Disposal.*	*Remarks.*
17. Lt. F. A. S.	20	Artillery Observer.	100	100	50	135/90	75 93 99	Sick leave.	Observer on previous case. Dazed not unconscious. Good work on return. Awarded D.F.C.
18. Lt. D. J. M.	19	Artillery Pilot.	70	65	25	118/78	84 91 144	England.	Crashed three weeks ago unconscious 45 minutes. Hospital since. Headache. Vertigo. ? Fractured Base.
19. 2nd Lt. C. W. H.	19	Scout Pilot.	200	92	25	115/74	63 79 92	England.	Hit tree crashed unconscious few seconds. Now feels fit but lazy.
20. Lt. R. H. R.	25	Scout Pilot.	20	130	40	130/80	60 66 72	Sick leave.	Crashed ten days ago hit head dazed. Three days later flew again and found he was useless. Very good work on return.
21. Lt. R. D. D.	20	Scout Pilot.	20	100	30	125/90	76 108 108	England.	Crashed three weeks ago unconscious ten minutes. Hospital one week. Since lost all confidence in the air.
22. 2nd Lt. F. A. P.	26	Scout Pilot. 2½ years in infantry.	22	80	25	120/65	89 122 155	England.	Two crashes in succession. Last one due to losing his head. Dazed. Headache. Very jumpy
23. Lt. E. G. McM.	30	Scout Pilot.	25	90	65	115/70	67 93 91	Sick leave	Crashed ten days ago unconscious one minute. No confidence next time up. Now fit and keen No headache. Did not return.
24. Lt. K. G. P. H.	19	Scout Pilot.	170	190	60	138/70	—	Duty to H.E	Crashed 14 days ago unconscious three days. Now feels absolutely fit.
			AVERAGE	104·0	38·4	127/81	77 88 99		

fitness with the pilot who flies by day. This result is occasioned partly by the fact that casualties being relatively small, there is more chance of the 'unfit' surviving as opposed to the 'fit'; but mainly by the unnatural mode of life and consequent irregularity of meals, lack of exercise, and in the hot months more especially lack of sleep. This point will be referred to later.

In view of the hypothesis that the 'fatigue test' is an indication of the tone of the respiratory centre, and assuming that the tone of both the higher and medullary centres is likely to be affected by cerebral concussion, 24 cases have been collected in Table III of pilots who have recently been concussed as the result of a crash.

It will be seen that the results are considerably lower than those obtained in the series of tired pilots. Further analysis of the concussion series, however, reveals the interesting fact that if they are divided into two categories, viz. (*a*) those who were evacuated to England, and (*b*) those who were considered to be so little affected as to be likely to be fit for active service after three weeks' sick leave, the latter reach a high level of excellence on the manometer tests, while the former fail.

Of the sick leave series only two failed; both reported sick in England, and were found permanently unfit for flying to the great disgust of one of them (Case 23). The temperamental fitness of the other (Case 4) was, however, open to question. All the ten who returned did excellent work. Case No. 13, in spite of having been unconscious for 15 minutes, was so little affected that he was flying again ten days later, and during the past three months has destroyed several E. A., and been awarded the D.F.C. and D.S.O.

The results set out in Table IV are the more noteworthy in that at the time these officers were in hospital the writer had not seen Flack's paper, nor had he learnt the value of the manometer tests. That is to say, the results of these tests carried little if any weight in arriving at a prognosis.

TABLE IV. CONCUSSION SERIES

Subject.	*No. of cases examined.*	*Expiratory force in mm. Hg.*	*Seconds of sustaining 40 mm. Hg.*	*Blood pressure in mm. Hg.*	*Sitting pulse.*	*Standing pulse.*	*Exercise pulse.*
All concussion cases	24	104·0	38·1	127 81	77	88	99
(*a*) Granted sick leave or returned to duty.	12	120·4	48·6	131/85	74	85	93
(*b*) Evacuated sick to England.	13	87·6	27·6	123 76	79	91	103

Pulse Rate.

Reference to the following table (No. V) shows that the home establishment series is characterized on the whole by a quiet pulse, the rate being considerably faster in night-fliers than day-fliers. In the concussion series the rates are somewhat higher, due entirely to the faster rate in those cases that had to be evacuated sick to England. For the sake of comparison, included in the table is

TABLE V. PULSE RATE AND BLOOD PRESSURE

	1	2	3	4	5	6	7	8	9	10	11
Subject.	*No. of Cases examined.*	*Sitting Pulse.*	*Standing Pulse*	*Exercise Pulse.*	*Blood Pressure in mm. Hg.*	*Percentage Number of abnormal Pressures.*	*Percentage Number of Systolic Pressures above Normal.*	*Percentage Number of Diastolic Pressures above Normal.*	*Percentage Number of Pulse Pressures above 40 mm. Hg.*	*Percentage Number of Systolic Pressures below Normal.*	*Percentage Number of Diastolic Pressures below Normal.*
I. All pilots and observers to Home Establishment.	91	72	85	95	123/78	68·2					
(*a*) Bristol Fighter and D.H.	20	71	84	93	121/74	65·0	35·0	20·0	30·0	15·0	10·0
(*b*) Scouts.	26	70	83	90	121/79	69·2	38·5	30·7	23·0	19·0	19·0
(*c*) Artillery.	24	71	84	94	125/80	60·0	4·00	25·0	30·0	5·0	5·0
(*d*) Night-flying.	21	76	89	100	127/78	90·5	28·5	38·0	57·0	4·7	19·0
II. All concussion cases.	24	77	88	99	127/81	70·8	45·8	37·5	33·3	4·0	12·5
(*a*) Granted sick leave and returned to duty.	12	74	85	93	131/85	83·3	66·6	50·0	41·6	0	0
(*b*) Evacuated sick to England.	12	79	91	103	123/76	58·3	25·0	25·0	25·0	8·0	25·0
III. Permanently unfit for flying.	29	87	100	110	130/82	85·7	50·0	43·0	50·0	0	10·7

a summary of the results obtained in a series of officers found permanently unfit for flying for various reasons: these, it will be seen, have on the average rapid pulse rates.

Blood Pressure.

This has been analysed as follows, but it must be admitted that the results of blood-pressure estimations are too variable to allow of any very definite conclusions being drawn.

The blood-pressure results have been collated as follows:

a. The average systolic and diastolic-pressures are noted.
b. The percentage number of abnormal readings is noted.
c. The percentage number of systolic-pressures above and below normal, of diastolic-pressures above and below normal, and of pulse-pressures above normal are noted.

The normal limits have been taken as:

i. Systolic—110 to 125 mm. Hg.
ii. Diastolic—70 to 85 mm. Hg.
iii. Pulse pressure—45 mm. Hg or lower.

It will be observed that column 6 is not equal to columns 7 to 11 added together, but considerably less. This is because a blood-pressure reading may be abnormal in more than one direction. For example, a reading such as 170/110 mm. Hg is abnormal in three directions, the systolic, diastolic, and pulse-pressures being all above normal.

The chief points to which attention is directed are first the high average of the systolic-pressures in all groups, and secondly the large percentage of abnormal pressures. The abnormality tends considerably towards high readings than towards low, and is most pronounced in concussion cases granted sick leave and the permanently unfit. These high readings have in no case been associated with arterial or renal changes, and are presumably to be looked upon as an indication of the strain of active service. It is only in high-altitude pilots, night-fliers, and the bad concussion cases that we find an average diastolic-pressure below 80 mm. Hg and any considerable percentage of cases with subnormal blood-pressures. In the night-flying group this is associated with a somewhat rapid pulse and large pulse-pressure, and is probably due to that general lack of condition to which reference has already been made (*vide* Table I. Cases (d) 1, 7, 9, 12). In the high-flying pilots (*vide* Table I. Cases (a) 1, 2, 10, (b) 6, 11, 17, 25, 26) it is more common to find a pulse below rather than above the normal and a normal pulse-pressure, and it is rather tempting to suppose that the condition is a result of repeated exposures to lowered oxygen pressures.

In order to determine the value of the examination employed, a series of officers found in the field permanently unfit for flying has been collected. All these officers had given practical proof of incapacity in the air in some way or another. No attempt is made to analyse the series, which is somewhat heterogeneous in character, including as it does such different disabilities as sickness in the air or shortness of breath on the ground.

TABLE VI. PERMANENTLY UNFIT FOR FLYING

Serial Number, Rank, and Initials.	*Age.*	*Hours flown on Active Service.*	*Remarks.*	*Expiratory Force in mm. Hg*	*Seconds for Sustaining 40 mm. Hg.*	*Pulse. Sitting. Standing. Exercise*	*Blood Pressure in mm. Hg*	*Remarks*
1. 2/Lt. P. W. A.	20	3	Passed by C.B. as observer only.	50	16	77 89 94	130/70	Undersized; B ii. for ground work. Fainted twice in England at 9,000 feet and once in France.
2. 2 Lt. O. H. B.	19	8	Passed by C.B. as observer only. Congenital Torticollis.	88	3	79 101 112	120/70	Attacks of blood rushing to head and everything goes black. Insomnia 14 days. Category B i.
3. 2/Lt. A.W.M.B.	19	10	When training had to change from scouts to D.H. 4 as stunting made him giddy. Pilot.	50	29	74 111 133	138/94	Very poor physique. Bad peripheral circulation. Giddy in the air. Cannot land properly. Category ?A after training.
4. Lt. T. R. D.	26	8	Always sick at 8,000 feet in England. Pilot.	80	20	68 75 81	125/80	Dizzy and fainted 10,000 feet. Crashed. Test flight fainted 12,000 feet. Pain in ears. Invagination both drums on landing. No permanent Eustachian obstruction. Category A.
5. Lt. H. D.	20	16	Pilot. Not passed by C.B.	78	15	126 129 150	140/100	Cannot face the lines. Twitching of muscles of limbs and face. Profound apprehension. Diffuse sweating. Thyroid not enlarged. Evacuated sick.
6. Lt. C. I. F.	19	29	Sick and giddy when training. Never a stunt pilot.	150	50	78 84 90	112/90	Giddy in the air and increasing dislike of flying of any kind. Ears normal. Category A.
7. 2/Lt. L. L. G.	23	2	Stopped flying scouts in England because he was no good and got giddy when stunting.	—	—	74 89 95	135/78	Views prospect of flying with dread. Cannot sleep or eat. Category A.

8. Sgt. G.	22	30	No shortness of breath. C_2H_5OH. Observer.	100	15	130 146 146	154/85	Bad type. Pilots will not fly with him. No distress on exertion. Alcoholic
9. 2/Lt. W. R. G.	19	125	Passed by C.B. fit as observer only. D.N.S. resected 1916. Vomited in air in England.	80	24	64 76 79	135/85	Increasing giddiness and nausea in air. Auto-inflation normal. No determination.
10. 2/Lt. P. H.	33	85	Passed by C.B. as observer only. Never been strong.	—	—	67 78 86	130/75	Mitral Regurgitation. Neurasthenia. Category B iii. Shaky and hysterical.
11. Lt. H. V. H.	23	90	No medical examination. Observer.	65	18	120 124 135	168/88	Giddy in air, faints on the ground. Tremor + + . Evacuated sick to England.
12. 2/Lt. E. A. K.	20	15	Mother neurasthenic. Neurasthenia 1916. Classified D 3 for infantry. Passed by C.B. Pilot.	—	—	98 111 113	125/80	When flying comes over all of a tremble. Cannot keep still. Tremor + + .
13. Lt. C. F. K.	25	0	P.H. Rheumatism. Gets hot and sweats all over when flying and has praecordial pain. Pilot.	50	38	101 124 128	125/85	Recently had P.U.O. Fainted twice in convalescence. Not confident about flying. Typical case of the effort-syndrome.
14. 2/Lt. R. A. L.	20	5	Not passed by C.B. Had to stop playing games at 18. Pilot.	—		93 111 118	124/80	Dizzy in air. Cannot spin. Sick in the stunts. No confidence and wants up. Very glad to give up flying. Category A.
15. 2/Lt. G. T. H. L.	23	25	18 months infantry France. No medical examination. Observer.	—	—	87 92 100	122/72	Bad sailor. Sick every time he has flown. Applied to depot for employment. Category A.
16. Lt. R. N. T. L.	22	54	Always been nervous. Bad sailor. Cannot dance. Not passed by C.B. Observer.	70	22	80 94 102	128/75	Giddy in the air: test stalk. No determination. Category A.
17. Lt. W. T. M.	28	15	Not passed by C.B. Pilot. Breakdown in 1914. Never fit since and realizes his limitations.	90	39	105 113 127	120/65	Finds flying exhausting. Effort syndrome. Dyspnoea on exertion. B.P.

TABLE VI. PERMANENTLY UNFIT FOR FLYING (*continued*)

Serial Number, Rank, and Initials.	*Age.*	*Hours flown on Active Service.*	*Remarks.*	*Expiratory Force in mm. Hg.*	*Seconds for Sustaining 40 mm. Hg.*	PULSE. *Sitting.* *Standing.* *Exercise.*	*Blood Pressure in mm. Hg*	*Remarks.*
18. 2/Lt. J. L. P.	25	2	No medical examination. Pilot.	—	—	98 113 120	125/96	Always hated flying and said so in England. Cannot look out side of machine, as it makes him giddy. Loses his head landing. Insomnia. Category A.
19. 2/Lt. A. R.	19	8	Passed by C.B. as observer only. Height 5 feet 1 inch. Weight 9 stone.	72	30	93 111 117	125/90	Sick every time he flies, and not tall enough to fight his gun. Category B ii.
20. 2/Lt. T.	18	2	Passed by C.B. Complained in England of giddiness, praecordial pain and dyspnoea on exertion. Pilot.	—	—	70 75 95	135/65	Pants at 6,000 feet, and vomits on landing after stunting. Very distressed after a sharp walk. Fainted at 15,000 feet on bar. Immature, may develop. Category B ii.
21. 2/Lt. C. E. T.	28	20	Passed by C.B. as observer only.	70	21	80 88 106	140/90	Never fit since he began flying. Dyspnoea at 10,000 feet, syncope at 17,000 feet. On Flack's bag fainted at 17,000 feet. Wind up.
22. 2/Lt. J. L. T.	18	20	Passed by C.B. as observer only. Always felt faint and sick in the air in England.	80	35	101 102 107	130/105	15,000 feet using O, intermittently—thinks he fainted, and can remember nothing till he landed. Immature, may develop later.
23. Lt. J. H. U.	19	20	Not passed by C.B. All right flying in England. Pilot.	60	25	100 107 123	120/70	Increasing fear of crossing the lines. Short of breath on ground lately. A.B. ¼ in. ext. L.N.L. Probably effort syndrome.
24. Lt. C. A. V.	27	30	Rh. Fever 1917. 3 times rejected for infantry. Very bad sailor. Sick in air in England. Pilot.	15	35	87 97 107	134/90	Sick flying. Dyspnoea in air and on ground. Wretched physique. Left Eustachian obstruction. Old T.B. Rt. apex. B ii.
25. 2/Lt. W. W.	24	40	Bad sailor. Sick in air in England. Pilot.	—	—	78 100 120		Sick after one vertical bank. Does not know what would happen if he got into scrap. Category A.

26. 2/Lt. G. W.	25	12	Passed by C.B. as observer only. Bad sailor, cannot waltz.	—	—	72 100 106	125/65	Sick every time he flies. Septic tonsils. Evacuated to England.
27. Lt. G. B. W.	28	30	Passed by C.B. as observer only. Bad sailor. Sick in air at home.	110	30	73 90 95	135/95	Often sick in the air and always so on rough days. Ears normal.
28. Lt. R. N. W.	19	10	Passed by C.B. Not allowed to play games by Doctor's advice. 8,000 feet in England, felt faint and had praecordial pain. Pilot.	40	20	79 97 101	123/90	Nearly fainted at 5,000 feet. Fainted twice on ground recently. Cardiac arrhythmia. Debility. May develop after training.
29. Lt. E. W. W.	19	15	Sick once in England. Pilot.	70	45	85 92 98	125/90	Sick every time he does a vertical bank. Last time fell over on joy stick, spun from 4,000 to 500 feet and was pulled out by observer. Rt. Eustachian obstruction. Taken up on test flight and vomited all over machine. Category A.
			Average . .			87 100 210	130/82	

Of the 16 pilots, 15, i. e. 94 per cent., had either not been passed by the Commissions Board, or gave a flying history while in England suggesting that their retention as flying officers was at any rate open to question. The remaining pilot, who had been passed fit, was a confirmed neurasthenic with a bad family history, and had already been classified D iii for the infantry. Of the 13 observers, nine only had been before the Commissions Board, *and all of these had been passed 'fit as observer only'*.

Taking the series as a whole it will be seen that the manometer results are bad, the average systolic pressure is well above normal (130 mm. Hg), while the percentage number of high systolic, diastolic, and pulse-pressures is distinctly high. At the same time the pulse rates are greatly in excess of those obtaining in any other series. Compared with the tired Bristol Fighter group, the sitting pulse shows an increase of 22 per cent., the standing of 19 per cent., and the exercise of 18 per cent.

This series may therefore justifiably be looked upon as confirmatory evidence of the value of the special examination employed.

The temperamentally unfit have been divided up into three groups:

(*a*) Those reported as temperamentally unfit by executive officers, an opinion for which no medical confirmation is available.
(*b*) Those in which a diagnosis of temperamental unfitness has been originated or confirmed by medical evidence.
(*c*) Psychopaths.

(*a*) This class is of scientific interest only in so far as its members *pass all the tests* (*vide* Table VII).

Three out of the eight cases returned to squadrons and completely justified their retention (*vide* especially Case 8).

(*b*) It is with this class that we are more particularly concerned. As a class it is characterized by the presence of physical signs. Nearly all the cases appeared to be in a state of trepidation and apprehension, and loss of emotional control was a prominent feature. Unlike the next series, the incapacity was attributable in about half the cases to some particular incident, such as a crash or a narrow escape. The general physique was distinctly below the average, and the ratio of pilots to observers was as 14 to 3. *Of the six observers all had been passed by the Commissions Board 'fit as observer only'*.

It will be seen that on the expiratory force test the series works out at 87 mm. Hg, i. e. well within the standard, but considerably below the figures reached by tired pilots and observers. On the fatigue test, however, the figure (28·8) is not far above that given by a series of pilots taken off flying through stress (*vide infra* and Report No. 7, Table XII, pp. 116–18).

(*c*) *Psychopaths.* The writer is not convinced of the soundness of this term, but proposes to retain it for want of a better one. Individuals belonging to this class usually, but not always, have a neuropathic family or past history. As a general rule they have never been confident in the air from the outset, and at the time

they reach hospital have developed a pronounced anxiety neurosis, the most of which is flying and not fighting. *Ill at the core with pilots.* A history of a crash or a particularly unpleasant experience is rare, and shock is not apparently an actiological factor. One and all look worried and depressed, taciturn, and disinclined to 'open out', while the majority appear unable to state with any precision why it is they do not like the air. Depression is undoubtedly present, and physical signs are conspicuous by their absence. The disability, in fact, is mental and remains mental, and their decision to give up flying has often struck the writer as being somewhat cold-blooded.

Judged by manometer results, the psychopath retains a high degree of physical fitness, the pulse rate is barely above the normal, the average systolic and diastolic pressure is not high, while out of nine cases there are only two (22·2 per cent.) with supernormal systolic, and only one (11·1 per cent.) with supernormal diastolic readings (*vide* Table X).

Pulse Rate and Blood Pressure.

In groups (*a*) and (*c*) the pulse is not rapid, in fact the former gives the slowest rate of any series. The number of cases examined is not, however, sufficient to allow of any definite conclusions being drawn either as regards pulse rate or blood pressure.

In group (*b*), on the other hand, the pulse rate is on the high side, the average systolic pressure is 130 mm. Hg, while half the cases had systolic pressures above 125 mm. Hg.

Taken in conjunction with the manometer tests, these results show that the temperamentally unfit is unstable physically. The most natural conclusion is that certain individuals are so constituted that they react to strain by alteration of their physical state, or in other words, that by reason of their temperament they will necessarily become physically unfit when exposed to strain. This lack of resistance appears to be a characteristic of the general 'make up' of the individual, and it must be supposed that the lack of inhibition in the higher nervous centres paves the way for a spread of nervous impulses; this in turn gives rise to a variety of physical phenomena, the main feature of which is overaction. Thus we frequently see in the somatic system overaction of various neuro-muscular groups, more especially of the speech mechanism, while in the autonomic system it is displayed by overaction of the heart (rapid and disordered action), of the skin (sweating), of the gastric mucosa (hyperacidity), and possibly of the adrenal glands (raised blood pressure), while it is also not impossible that the loss of weight which frequently occurs in these cases is due to a general increase of metabolism secondary to changes in the autonomic system.

The practical proof that an individual of this type is unfitted for service flying is supplied by his failure to withstand mental strain of such a degree as to affect the more stable individual only temporarily or not at all, while confirmation of his instability is provided by physical as well as mental examination. Temperamental and physical unfitness are accordingly not separate but closely allied things, and the patient's frequent statement, 'I cannot go on,' accurately sums up the situation.

TABLE VII. TEMPERAMENTALLY UNFIT (*a*)

Serial Number, Rank, and Initials.	*Age.*	*Hours flown on Active Service.*	*Type of Machine.*	*Previous History.*	*Expiratory Force in mm. Hg.*	*Seconds for Sustaining 40 mm. Hg.*	PULSE. *Sitting.* *Standing.* *Exercise.*	*Blood Pressure in mm. Hg.*	*Remarks.*
1. Lt. H. B. P.	19	93	Scout.	Passed by C.B. Pilot. 210 hours as instructor.	85	45	70 88 91	120/82	Slight crash two days ago. Dazed; sleeping badly, ten days. No loss of confidence in air. Quite fit on discharge.
2. Lt. A. C.	19	30	Bristol Fighter.	Pilot.	85	55	73 86 94	140/80	Complains of dyspepsia. Flatulence and dizziness at any great altitude. Has had to return from patrols. No physical signs.
3. Lt. P. S. B.	20	60	Bomber.	Pilot.	90	42	70 76 86	110/70	Ordinary symptoms of oxygen want during and after long shows at 18–20,000 feet.
4. 2nd Lt. D. S.	22	14	Bomber.	Observer.	170	60	64 74 76	136/85	Headache after high flying.
5. 2nd Lt. A. E. B.	22	42	Artillery.	Pilot.	120	35	65 75 86	132/70	Shot down one month ago. Since then feels sick in the air. Returned to another sqdn. and is doing well.
6. 2nd Lt. C. R. A.	23	20	Artillery.	Joined as Pilot against his will. Never been at all keen on flying.	—	—	71 82 88	105/65	Feels 'unwell' in the air.

7. Lt. J. E. H. C.	19	42	Bomber.	Previously done a little artillery work and liked it. Observer.	90	42	71 86 98	112/85	Cannot look over the side at 10,000 feet, gets horrible sensation of height; seems isolated from the earth and almost wants to jump out. Returned to Artillery Squadron and since qualified as F.O.O.
8. Lt. J. L. R.	19	35	Scout.	Reported as T.U. by Sqdn. Cmdr in 1917; not agreed with on medical grounds, largely on account of age. Retained in R.F.C. and was posted to a sqdn. as gunnery officer. Felt he wanted to 'make good' in the air. Passed fit.	100	35	67 74 84	145/105	Brought down 9 E.A. in about three weeks and was then killed in aerial combat. Posthumous award of D.F.C.
				AVERAGE	106	45	69 80 88	125/81	

Three out of the eight cases returned to squadrons and completely justified their retention (*vide* especially case No. 8).

TABLE VIII. TEMPERAMENTALLY UNFIT (*b*)

Serial Number, Rank, and Initials.	*Age.*	*Hours flown on Active Service.*	*Type of Machine.*	*Previous History.*	*Expiratory Force in mm. Hg.*	*Seconds for Sustaining 40 mm. Hg.*	PULSE. *Sitting.* *Standing.* *Exercise.*	*Blood Pressure in mm. Hg.*	*Remarks.*
1. Lt. D. R. B.	19	45	Bomber.	Accepted by C.B. as observer only.	85	25	68 81 84	115/65	Shot down three weeks ago—uninjured. Since then lost all confidence, and could not face lines. Lost weight recently. Bad physique.
2. Lt. H. McE.	25	? 120	Artillery.	Pilot.	72	25	87 97 107	145/115	Giddy in the air no nausea. Lost confidence. Bad type. C.O. reports very adversely.
3. Lt. B. P. T.	22	25	Bomber.	Accepted by C.B. as observer only.	70	40	66 75 86	120/80	? Hit by splinter from A.A. 14 days ago. Giddy in air. Not much interest in flying.
4. 2nd Lt. F. W. F. T.	24	50	Artillery.	Accepted by C.B. as observer only.	80	35	115 127 124	170/110	Has gradually found strain of service flying too much for him. Collapsed in cock-pit when he saw E.A. approach. Now wind up.
5. Lt. C. M. D.	26	17	Scout.	Pilot.	120	20	66 85 95	113/80	Insomnia and nightmares. Will not admit loss of confidence.
6. Lt. S. W. C.	23	65	Scout.	Occasional vomiting in air. Previously examined following ? syncope at 4,000 feet and crash.	80	35	68 85 90	118/65	Feels faint at 12,000 ft. Finds flying a great strain, and thinks he will never make a scout pilot. Much worse since slight crash.
7. Lt. R. D. S.	23	20	Night.	Pilot.	110	30	95 99 117	115/85	Has never liked flying and has no wish to continue. Loses himself in the air and does not know position of machine.

8. Lt. R. P.	24	60	Artillery.	Never played games. Pilot.	50	20	65 70 75	145/100	Never felt comfortable since coming to France and has to fly by [illegible] moments.
9. Lt. S. H. E.	19	30	Artillery.	Passed by C.B. Crashed three times as pupil.	110	25	65 73 80	140/100	Completely lost confidence since being chased by two E.A. Sleeps well.
10. Lt. B. H.	21	5	Scout.	Took nearly a year learning to fly.	80	27	84 91 100	143/95	Cannot face the air. Hates sight of machine. Lachrymose. Not sleeping well.
11. 2nd Lt. C. P.	18	12	Bomber.	Passed by C.B. as observer only.	50	25	78 81 89	115/85	Headache and praecordial pain 12,000 feet. Shot at his own formation. Very tremulous. Immature, may develop.
12. Lt. E. E. B.	22	10	Artillery.	Several crashes in England. Pilot.	—	—	74 76 80	123/80	Feels nervous. Thanks flying a great strain, but is keen to have another shot at it. Feels sorry for his observer. Several crashes due to bad flying.
13. Lt. B. G. B.	24	30	Artillery.	No previous combatant service. Pilot.	85	17	85 100 109	132/75	On two occasions 'things have gone black' in the air. Stammering one week. Lost all confidence.
14. Lt. J. R. B.	22	25	Bomber.	All right flying in England. 120 hours. Pilot.	105	25	90 93 108	115/80	Lost all confidence since seeing a machine land without its under carriage. Has no wish to continue.
15. Lt. G. A. H.	24	? 120	Artillery.	Previously under observation on posting overseas with tachycardia. High B.P. and general apprehension. Pilot.	110	35	76 94 97	130/90	Felt better after his first flight in Sqdn. Now has little anxiety about flying.
16. Lt. R. F. C. M.	21	45	Bomber.	V.D.G. 1916. Pilot. 100 hours in England.	40	25	64 81 98	112/60	Shot down week ago [illegible]. Since then just loss of confidence in air, and disinclined to go over lines. Some emphysema.
17. Lt. R. L. P.	19	30	Bomber.	Passed by C.B. Pilot. Bad physique. 120 hours in England.	105	35	72 81 90	148/75	Crashed week ago [illegible]. Very nervous. Insomnia, shakiness, apprehension. Very tremulous.

TABLE VIII. TEMPERAMENTALLY UNFIT (*b*) (*continued*)

Serial Number, Rank, and Initials.	*Age.*	*Hours flown on Active Service.*	*Type of Machine.*	*Previous History.*	*Expiratory Force in mm. Hg.*	*Seconds for Sustaining 40 mm. Hg.*	PULSE. *Sitting.* *Standing* *Exercise.*	*Blood Pressure in mm. Hg.*	*Remarks.*
18. Lt. S. S. C.	28	12	Bomber.	Passed by C.B. Pilot.	45	15	77 89 104	125/80	Has never liked flying and has no wish to continue, as he cannot face the lines and admits to being terrified.
19. 2nd Lt. C. B. D.	20	45	Night.	Passed by C.B. Pilot 100 hours in England.	55	20	96 103 105	148/100	Crashed month ago—dazed—hospita since. Nightmares. Very tremulous. No headache. Does not think he can stick it.
20. 2nd Lt. H. J. C.	19	160	Bomber.	Passed by C.B. as observer only. ? Rh. Fe. at 7.	45	22	66 75 100	135/90	Two days ago felt giddy after scrap—was using O_2. Felt giddy ever since. Ears normal. Ht. nil except sinus-arrhythmia. Adverse report from C.O.
21. Lt. W. R. T. C.	22	$\frac{1}{3}$	Bomber.	Passed by C.B. as observer only. Never been strong enough to take active exercise. History of nervous debility. Sedentary life.	65	25	70 77 86		Congenita ?Ptosis (Rt.). Very tremulous. Sick in the air. Could not go on under any circumstances whatever. Would like to get back to civilian life.
22. Lt. E. F. S.	28	0	Bomber.	Has lived in South America. Pilot.	140	20	65 79 85	102/78	Pains in back—would prefer to go to warmer climate.
23. 2nd Lt. E. C. H.	21	120	Artillery.	Slight nervous breakdown 1915, driving cars at night. Pilot.	65	28	89 105 108	104/70	Completely lost confidence in the air. Now physically unfit G.S.; requires tonsillectomy.

24. Lt. J. T. B.	20	½	Scout.	Quite fit in England. Pilot.	130	35	77 101 106	116 85	Broke down first flight over lines and could not have faced lines again under any conditions.
25. Lt. A. N. P.	20	? 150	Artillery.	Pilot.	90	30	86 93 99	130/70	Headache after flying. Loss of confidence. C.O. reports: 'Has never done a good job of work'.
26. Lt. G. P. L.	19	70	Bomber.	Has done some good work. Pilot.	130	30	93 100 106	125/80	Very erratic in air—several minor crashes. Finds he cannot stand the strain, lachrymose.
27. Lt. W. S. E.	20	70 + 20	Bomber.	Did 70 hours on scouts, and transferred to 2-seater for fear of getting an E.A. on his tail. Pilot.	112	40	98 102 122	143 74	Thinks his vision is bad. V.A. 6/5 R & L. Entirely devoid of offensive spirit.
28. Lt. E. R. S.	27	40	Scout.	Seen active service with infantry and R.F.A. Pilot.	100	40	70 76 80	155 90	Says he enjoys flying, but appears lacking in determination.
				AVERAGE	87	28·8	80 89 98	130/83	

TABLE IX. TEMPERAMENTALLY UNFIT (c

(*Psychopaths*)

Serial Number, Rank, and Initials.	*Age.*	*Type of Machine.*	*Hours flown on Service.*	*Previous History.*	*Expiratory Force in mm. Hg.*	*Seconds for Sustaining 40 mm. Hg.*	*Blood Pressure in mm. Hg.*	Pulse. *Sitting.* *Standing.* *Exercise.*	*Remarks.*
1. Lt. C. M.	25	Scout.	25	Severe insomnia for three weeks at 15.	110	50	110/75	81 88 96	Quite happy in air, but thinks and dreams of flying all night. Profound insomnia. Worried and depressed.
2. Lt. E. N. A. R.	23	Artillery.	160	No war flying for several months. Pilot.	170	45	110/75	67 80 83	Never really happy in air. Increasing loss of confidence. Headache and insomnia. Looks very worried.
3. Lt. J. W. C.	24	Artillery.	15	Pilot.	170	75	115/75	64 74 78	Never happy in the air. Minor crash week ago destroyed all confidence he ever had. No wish to continue.
4. Lt. F. C. C.	23	Artillery.	100	Pilot. V.D.(G.) Aug. 1917.	95	38	138/84	84 94 101	Not fit since V.D.G. Gradually losing confidence. Now cannot face the air. Depressed.
5. Lt. G. W. M.	25	Bomber.	30	15 months with infantry in France. Pilot.	90	43	138/100	88 98 103	Shaky every time he flies. I cannot do a turn. Flying has always worried him. Depressed.

6 Lt. C. J. B. F.	20	Bomber.	70	Pilot	95	49	120, 70	72 89 94	Machine shot about four days ago. Now could not possibly face lines. Sleeps well—no dreams. Feels it
7. Lt. J. W. K.	27	Bomber.	15	Rejected by C.B. Passed by Admiralty. Pilot.	110	30	118, 85	75 91 100	Flying has always been a great effort and now has no wish to continue. Tried to jump out at 10,000 ft.
8. Lt. W. B. B.	22	Scout.	12	Passed fit in U.S.	85	60	120/70	64 86 99	Persistent headache. Cannot get over seeing bodies of occupants of hostile machine brought down behind our lines.
9. Lt. A. F. M	25	Scout.	15	Passed fit in U.S.	85	54	120, 75	69 86 96	Has never been happy in the air, and now hates it.
				AVERAGE	112	48·2	121/79	75 87 94	

TABLE X. TEMPERAMENTALLY UNFIT

Pulse Rate and Blood Pressure

Subject.	*Number of Cases examined.*	*Sitting Pulse.*	*Standing Pulse.*	*Exercise Pulse.*	*Blood Pressure in mm. Hg.*	% *Number of abnormal Blood Pressures.*	% *Number of Systolic Pressures above Normal.*	% *Number of Diastolic Pressures above Normal.*	% *Number of Pulse Pressures above 45 mm. Hg.*	% *Number of Systolic Pressures below Normal.*	% *Number of Diastolic Pressures below Normal.*
(*a*) By Executive Officers.	8	69	80	88	125/81						
(*b*) By Medical Officers.	28	80	89	98	130/83	67·8	50·0	36·0	39·3	7·1	10·7
(*c*) Psychopath	9	75	87	94	121/79						

Case 4 (Table IX) is an admirable example of the degree to which the emotions can be reflected in the cardiac-vascular system. He frankly admitted being frightened at the idea of flying over the lines, had a standing pulse of 127, and a blood pressure of 170–110 mm. Hg. Cases 2, 9, 10, 17, 19, 20, and 27 also show the same condition on a smaller scale. Case 19 was posted back to a squadron, but on arrival was unable to take a machine off the ground, to the great relief of his observer.

Discussion of Results.

It has been shown that pilots and observers whose condition, in the opinion of their commanding officers, warrants their transfer to England for what is somewhat euphemistically termed a rest, preserve a comparatively high degree of physical fitness as judged by the tests employed. The chief difference between individuals who have done their work at high as compared with those who have flown at low altitudes lies, not as might perhaps be expected in a poor performance on the manometer test, but in the more frequent occurrence among the former of blood pressures below the normal, with which is usually associated a small and rather slow pulse. Should this finding be confirmed, it not improbably owes its origin to an alteration of tone of the medullary centres brought about by repeated exposures to rarefied atmospheres.

Night-fliers, although having less hours in the air to their credit, are on the whole less fit than day-fliers, a condition attributable to their abnormal mode of life, lack of exercise, sleep, and so on (*vide* Table XI).

Other groups in which the manometer results attain a high level are: (i) individuals who have recently sustained concussion which has affected them so little as to warrant their return to duty either in a few days or after three weeks' sick leave, (ii) psychopaths who do not wish to continue flying, and (iii) a few cases reported on as temperamentally unfit by executive officers in which medical confirmation is lacking.

All these cases are about equally fit, judged by the manometer and pulse rates.

This leaves three groups, to which we will add for the sake of comparison a fourth, viz. Flack's series of 'pilots taken off flying through strain'.

i. Concussion cases evacuated to England.
ii. Permanently unfit for flying on medical grounds.
iii. Temperamentally unfit (excluding psychopaths).
iv. Pilots taken off flying through stress.

It will be seen from Table XII that, judged by the manometer, these groups are about equally unfit and have pulse rates considerably above normal, and the question arises, Have these results an explanation in common?

As regards the test for expiratory force, it would appear to the writer to depend chiefly on the power and tone of the expiratory and abdominal muscles, together with the ability of the individual

TABLE XI

Subject.	*No. of Cases examined.*	*Expiratory Force in mm. Hg.*	*Seconds for Sustained 40 mm. Hg*	*Sitting Pulse.*	*Standing Pulse.*	*Increase Pulse.*	*Blood Pressure in mm. Hg.*	*% No. of abnormal Blood Pressures.*	*% No. of Systolic Pressures above Normal.*	*% No. of Diastolic Pressures above Normal.*	*% No. of Pulse Pressures above 45 mm. Hg.*	*% No. of Systolic Pressures below Normal.*	*% No. of Diastolic Pressures below Normal.*
I. Day-fliers due for rest.	70	120·5	47·0	71	84	93	122–78	65·0	37·3	25·4	27·0	13·4	12·0
II. Night-fliers due for rest.	21	103·6	45·7	76	89	100	127–78	90·5	28·5	38·0	57·0	4·7	19·0
III. Concussion cases granted sick leave.	12	120·4	48·6	74	85	93	131–85	83·3	66·6	50·0	41·6	0	0
IV. Psychopaths	9	112·0	18·2	75	87	94	121–79	44·4	22·2	11·1	33·3	0	0
V. Reported temperamentally unfit by executive officers.	8	106·0	45·0	69	80	88	125–81						

TABLE XII

Subject.	*No. of Cases examined.*	*Expiratory Force in mm. Hg.*	*Seconds for Sustaining 40 mm. Hg.*	*Sitting Pulse.*	*Standing Pulse.*	*Exercise Pulse.*	*Blood Pressure in mm. Hg.*	*"% No. of abnormal Blood Pressures.*	*"% No. of Systolic Pressures above Normal*	*"% No. of Diastolic Pressures above Normal.*	*"% No. of Pulse Pressures above 45 mm. Hg.*	*"% No. of Systolic Pressures below Normal.*	*"% No. of Diastolic Pressures below Normal*
i. Concussion cases evacuated sick.	12	87·6	27·6	79	91	103	123/76	58·3	25·0	25·0	25·0	8·0	25·0
ii. Permanently unfit for flying on medical grounds.	29	76·0	28·0	87	100	110	130/82	85·7	50·0	43·0	50·0	0	10·7
iii. Temperamentally unfit (excluding Psychopaths).	28	87	28·8	80	89	98	130/83	67·8	50·0	36·0	39·3	7·1	10·7
iv. Pilots taken off flying through stress.	27	74	25	—	—		—	—	—				

to make a properly co-ordinated movement of expiration. It is difficult to assess its value and to gauge its significance, but as an empirical test it is clearly of considerable practical utility. It is interesting to recall that this test is in use in physical training schools in America, and an American pilot, who recently came under observation, recognized it as an old friend, and proceeded to blow the mercury out of the top of the tube (i.e. about 320 mm. Hg) without apparent effort, a performance which rather suggests that there is some 'knack' about it. The writer, although having a vital capacity of 5,000 c.c., and being above rather than below the average at standing the effects of high altitude, has never succeeded in passing Flack's minimum, i. e. 80 mm. Hg, although he can sustain 40 mm. Hg for nearly 70 seconds.

It is not proposed to enter into a discussion regarding the physiological significance of the 'fatigue' test, especially as the observations on the behaviour of the pulse during the test, large numbers of which have been made by Captains Corbett and Bazett, have not been collected. Certain points, however, merit attention. Firstly, it appeals to the sporting spirit, and the individual endowed with this is likely to do better than the one who is not. Secondly, it looks much easier than it really is, and the patient may consequently get a false impression of the effort required, and fail to carry out the necessary 'preliminaries'. As a result he does poorly at his first attempt, and makes amends at his second. This discrepancy has often occurred, and is looked on as an unsatisfactory point in the test.[1] Thirdly, determination is undoubtedly an important factor. In other words, the test is in some respects a psychological one.

Returning to the results set forth in Table XII, the question inevitably arises, What is stress, i. e. the condition met with in group iv? Clearly not the same condition which is found in the tired flying officer on transfer to England for a rest, nor can it be due to the effects of altitude alone, since it occurs in low fliers. An examination of Flack's Table XI, No. 13 of this series, pp. 22–4, reveals the fact that some of the cases (Nos. 7, 16, 21, 24, 25) had done comparatively little flying. Of these, No. 20 only flew once in France, and fainted at 14,000 feet. He was examined by the writer and was found to be suffering from the 'effort syndrome' (sitting pulse 140, exercise pulse 180) with enlargement of the left ventricle. He had never been able to play games on this account, and was sent home labelled 'permanently unfit'. Further, two cases (Nos. 1 and 2) and perhaps three (No. 7) had been doing long reconnaissances at 20,000 feet, without oxygen. At one time such cases were unfortunately common, but the writer has manometer records of two only (*vide* Table XIII).

It is well known that certain individuals who have done much high flying without oxygen gradually find the altitude at which symptoms

[1] This may perhaps be explained physiologically. During the first attempt owing to the large positive pressure in the thorax the large veins become filled, and this congestion on the right side of the heart may persist for a considerable time. Hence the second attempt is begun with a higher venous pressure and larger inflow into the heart.

TABLE XIII

Serial Number, Rank, and Initials.	*Age.*	*Remarks.*	*Hours flown in France.*	*Expiratory Force in mm. Hg.*	*Seconds for Sustaining 40 mm. Hg.*	*Vital Capacity in c.c.s.*	*Blood Pressure in mm. Hg.*	PULSE. *Sitting. Standing. Exercise*	*Remarks.*
1. Flt. S/Lt. R. P.	22	Pilot, D.H. 4.	200	50	15	4,000	—	—	Long reconnaissance at 18 21,000 ft. without oxygen. Gradual onset of disability to fly high. No loss of confidence.
2. 2/Lt. J. K. C.	20	Pilot, D. H. 4	120	50	19	4,000	—	—	Long reconnaissance at 18 21,000 ft. without oxygen. Feels effects after 3 weeks.
3. 2/Lt. E. S. P.	21	Pilot, D.H. 4. Malaria in Salonica. Still has attacks.	100	60	15	4,000	105 60	69 76 85	Long reconnaissance at 18 21,000 ft. Always uses oxygen when he can get it, as he feels done in without it. Fainted at 14,000 ft. using oxygen, but feeling no height. Cannot remember landing. Persistent headache and lassitude. Generally run down.
4. 2 Lt. W. F. N. (D.C.M.)	30	Observer, D.H. 4. Active service chiefly with infantry since 1914. Egypt, Gallipoli, and France. Always been very fit.	154	50	20		135 95	72 81 89	Long reconnaissance at 20 21,000 ft. Oxygen made him sick, so discontinued it, in spite of headache. Last two months has gradually got worse at heights. Now gets very short breathing above 15,000 ft., especially exhausted by slightest movement, can hardly walk on level ground, has to lie down, short of breath, on ground, never free from headache. No energy. Could short for a week. No loss of confidence. Has not flown in war until recently.
		Average		52·5	17·25	4,000			

of oxygen-want supervene getting progressively lower, a condition which may persist for many months at least. The physiological explanation of this condition is at present undetermined. In all the cases investigated it was associated with evidences of fatigue with disinclination for effort, both mental and physical, and it is therefore not improbable that the condition is primarily cortical in origin.

As regards the four last-mentioned groups, some factor other than altitude must be sought to explain the results, and the most reasonable supposition is that in certain of the cases flying did not cause but merely unmasked a pre-existing condition. It is at least remarkable that if we take a series of pilots who have recently sustained concussion, we find that half of them are fit to return to duty in three or four weeks and pass the manometer tests, while the other half, who are more severely affected, and have to be evacuated to England, fail to pass the tests. These results cannot be explained by a greater degree of concussion in the latter, and they would therefore appear to be due not so much to the actual concussion as to the constitution of the individuals concussed. In other words, it is not concussion of the brain which chiefly matters, but concussion of the mind. In the same way in the temperamentally unfit, and to some extent in those found permanently unfit on medical grounds, the unfitness lies largely in an undue susceptibility to mental shock, to which these individuals react primarily by various mental and psychical phenomena, and secondarily by various alterations in their physical state.

It is here that the importance of determining the pulse-rate and blood-pressure comes in. This investigation has not aimed at studying the mechanical efficiency of the cardio-vascular system or of estimating the response of the heart to exercise and so forth. This has already been done by Starling in the laboratory and by Lewis in the ward. Remembering that emotional disturbances are readily reflected in the circulatory apparatus, it is permissible to look to this apparatus for information in the matter of 'temperament'. The results show that whereas the normal stable individual, when due for a rest after 150 to 500 hours' war-flying, preserves a comparatively slow pulse and a resting blood-pressure within normal limits, the unstable individual with little war-flying to his credit, who has failed to rise to the occasion or has succumbed to some minor accident, has a definitely faster pulse, and a blood-pressure which is frequently abnormally high (e. g. 170/110 mm. Hg).

Lack of resistance to strain appears to be part of the general 'make up' of the individual, and it must be supposed that the lack of inhibition in the higher nervous centres paves the way for a spread of nervous impulses, which give rise to a variety of physical phenomena, characterized by overaction (tachycardia, tachypnoea, sweating, gastric hyperacidity, arterial hyper-tension, and so on). It is believed that this test has a value altogether apart from flying in general and from high flying in particular; that this value consists in the assistance which it affords in assessing both the degree of shock sustained by the nervous system and also the susceptibility to shock. Looked at in this way it is a test not so much for fatigue

as for fatiguability, and it is suggested that certain conditions which are at present called 'flying stress' could more appropriately be designated by the title 'flying distress'.

Conclusions.

1. The majority of pilots and observers transferred to England for a rest preserve a comparatively high degree of physical fitness, day pilots being fitter than night pilots.

2. The flying temperament is of less importance in the field than the fighting temperament.

3. A study of the pulse-rate and blood-pressure together with the manometer tests affords valuable information in assessing temperament and an individual's susceptibility and reaction to mental trauma.

4. A distinction should be made between flying stress and flying distress.

9.—RESPIRATORY TESTS FOR ABILITY TO STAND HIGH ALTITUDES

BY

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Recently a number of airmen (seventy-three) have been examined by respiratory tests, including officers who have proved themselves to be efficient at high altitudes as well as many who have failed to stand this strain. The former class have usually done a large number of hours' flying and have come to hospital because of the resulting exhaustion, whilst the latter have often done very little active-service flying, so that the two classes are not very comparable. None the less, very marked differences are seen, and the results seem worth recording, since those who have proved to be good at high altitudes are found to be much fitter than the others, as judged by these tests, in spite of the fact that they are much more exhausted.

The tests to which they have been subjected are as follows:- their expiratory force has been determined by the U-tube, as well as their power to withstand fatigue when maintaining the mercury at 40 mm.; their vital capacity, tidal air, and respiratory rate have been measured, and the ventilation per minute (i.e. the amount of air breathed per minute) has been noted. From the results obtained it would appear that these latter measurements are also very valuable in estimating a man's power of enduring oxygen-want.

These methods of examination were adopted as the result of observations on patients during Dreyer altitude tests (see Report 4 of this volume), since it was found that those who reacted to want of oxygen by quickening rather than deepening their respiration were almost invariably bad at standing altitudes,[1] as also were those with a low vital capacity, or very high air consumption when sitting at rest.

A. Methods.

The methods used with the manometer need not be elaborated. It has been employed according to Flack's directions. (See Report 7 of this volume.)

The vital capacity has been determined by using an ordinary Siebe-Gorman 2·5 litre water-meter for measuring gases, any over-blowing of the meter being prevented by the use of a football bladder as a safety-valve. A mouthpiece which can be removed and disinfected is connected to the meter by rubber-tubing in which

[1] The references in the tables to altitude tests refer to cases described in Report 4 of this volume.

a T-tube has been inserted, and to the third limb of the T-tube a football bladder is attached. Even with the bladder inserted in this way the meter may still be overblown if care is not taken; but if the resistance of the tubes between the patient's mouth and the meter is made rather greater than that to the bladder, most of the air passes to the bladder and only the overflow to the meter. With this precaution overblowing of the meter is impossible. At the end of the expiration a light clamp is put on the rubber tube near the mouthpiece, and then the air in the bladder is expelled through the meter. In this way quite accurate results can easily be obtained.

The ventilation per minute has been determined by making the patient breathe through a system of valves, so that the expired air passes through a Siebe-Gorman meter. This creates some resistance to expiration, and to obviate this an ordinary air-cushion

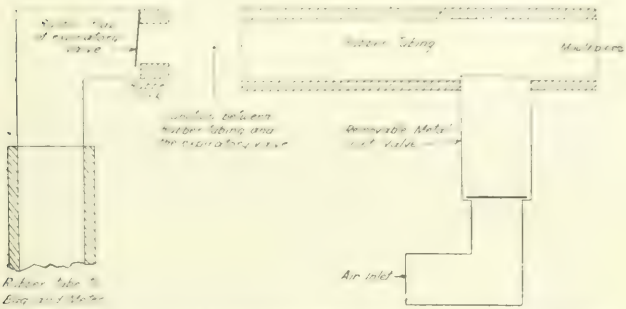

DIAGRAM SHOWING TUBE MOUTHPIECE DISCONNECTED FROM EXPIRATORY VALVE.

is inserted as a bag, making again a T-connexion with the tube between the valves and the meter. The patient is made to wear a nose-clip and to breathe through this system for two minutes, during which time his respirations are carefully counted. At the end of the time the tube is clamped near the mouthpiece, and the air-cushion is emptied through the meter, the total amount of air breathed in two minutes being thus measured. In this way the ventilation per minute is obtained. Some difficulty was experienced in obtaining valves which would be efficient and yet could be easily sterilized. Recently a piece of $\frac{3}{4}''$ bore rubber-tubing four inches in length has been employed as a mouthpiece, as this can easily be sterilized. Its connexion with the inlet and exhaust-valves may be seen in the diagram. The inlet valve used has been the light expiratory valve from a French 'Tizot' gas-mask, the valve being arranged so that it opens only during inspiration instead of expiration; the expiratory valve has been made by using a light flap of rubber sheeting. It is probable that in using these valves some slight leak occurs, especially in quiet breathers, so that the ventilation values obtained may not be absolute, but they serve

sufficiently well to give a good relative test for comparison of different airmen, and compare closely with figures given by Haldane and his co-workers.

The respiratory rate is determined by counting the respirations during the time that the patient is breathing through the meter. If this rate differs widely from a normal respiratory rate, then his rate when breathing naturally at rest is also observed for comparison. Slowing of the respiratory rate as the result of breathing against the slight resistance of the apparatus is fairly often seen in good types, while a quickening of the rate is only found in those who are unable to stand altitude well, or in those who are temporarily ill (e.g. influenzal debility).

The tidal air is determined by dividing the amount of air used per minute by the number of respirations. With the good types the average tidal air found was 523 c.c. and the average respiration rate 14·1, thus affording some confirmation that the methods in use give fairly normal figures.

B. Results.

In Tables I, II, and III may be seen collected the results that have been obtained by these methods. In Table I are included those who have proved themselves to be efficient at high altitudes, though the figures are somewhat affected by the inclusion of many very tired men. Table II contains those who are known to have been bad at high altitudes, while Table III consists of a few whose condition at high altitudes has never been put to the test, together with some border-line cases suffering from mild symptoms of oxygen-want.

It will be noticed that considerable differences exist between these classes, and the results with the different tests may be discussed shortly.

U-Tube Manometer. An average expiratory force of 96 mm. was found in those good at high altitudes, of 81·8 mm. in those who were bad, and 100·8 mm. in those whose behaviour at high altitudes was uncertain. Similarly the U-tube fatigue test gave an average duration of 57·3″ in the first class, of 38·7″ in the second, and of 47·4″ in the third, so that those whose behaviour was uncertain come roughly midway between the good and bad types (except for the maximum expiratory force which appears to have been slightly lowered by fatigue in the good type). This, too, in spite of the fact that the average number of hours flown was 240 hours in the good, 131 in the bad, and 175 in the uncertain type. Though fatigue has undoubtedly lowered the figures obtained in many cases, yet it must mask rather than cause the contrast observed, since there can be no doubt that the manometer results have been lowered in the good type by fatigue, so that originally their average must have been very high. Also it is noticeable that the average figures obtained even in the bad class are only very slightly below the Commissions Board minimum standards, and that only in the fatigue test. Of the good type, 34·6 per cent. are below the minimum standard expiratory force of the Commissions Board

TABLES

TABLE I. GOOD AT ALTITUDES

No. and Name.	History	Flack's Manometer. Max.	Flack's Manometer. Duration at 40 mm.	Vital Capacity.	Ventilation per minute.	Respiratory Rate.	Tidal Air.	V. M. V. C	Factor.	Remarks.
1. H. C. B.	Good by Dreyer's test and on mountains. No high flying. Dreyer test (No. 5).	120	85"	5375	8750	16	546	1·63	26	
2. J. B.	80 hrs. Boarded P. U. F. Dec. 17. Tested May 1918 by Dreyer's method and found fit to fly below 10,000 ft. (Dreyer, No. 37.)	100	68"	3850	7450	13	570	1·9	25	Limited to 10,000 ft. owing to his old history of cardio-vascular debility. Fit at 18,000 during test.
3. G. D.	156 hrs., Bristols. Tired. Has educated himself to deep breathing at altitudes, finding it useful.	198	60"	3600	8800	10	880	2·45	25	Evacuated to England for rest and H.E.*
4. D. C.	No high flying. Good at altitudes when tested by Flack's bag.	140	126"	5500	6250	15	416	1·14	17	
5. H. E.	105 hrs. on day bombers. Recently concussed.	75	40"	3700	5500	10	550	1·5	15	Respiratory rate without tube, 11. Sent to convalescent hospital.
6. D. A. S.	120 hrs. on Bristols. Fracture of carpus otherwise fit.	85	44"	3900	5600	16	350	1·4	22	Evacuated to England
7. J. L. B.	M. O. but has proved to be very good at high altitudes.	80	69"	4950	6000	10	600	1·21	12	

* H.E. indicates for duty on Home Establishment in England.

TABLE I. GOOD AT ALTITUDES *(continued)*

No. and Name.	*History.*	*Black's Manometer.* *Max.*	*Duration at 40 mm.*	*Vital Capacity.*	*Ventilation per minute*	*Respiratory Rate.*	*Tidal Air.*	*V. M. V. C.*	*Factor.*	*Remarks.*
8. R. Y. I.	450 hrs. day bombing. Admitted to hospital for debility after influenza. Very good type but pulled down by influenza.	75	65″	5100	8600	22	390	1·7	37	Discharged to duty after one week. Very excitable type. Duty at his own request. Posted as missing a week or so later.
9. J. T. J.	360 hrs., Scouts. Very good type. 35 Huns. Admitted for debility after influenza.	115	50″	3200	5917	18	328	1·8	32	Discharged to duty after ten days at his own request.
10. J. T. J.	Readmitted 18 days after discharge (see above), having had 50 hrs. in the air and 14 Huns since discharge. Very tired after flying, dreaming of flying, and walking in his sleep. Some loss of weight.	90	38″	3200	7100	16	433	2·2	35	Evacuated to England for rest and H.E.
11. D. R. D.	90 hrs., 13 in France. Scouts. Is all right at 16,000 ft., but has trouble with his ears. Has Eustachian obstruction and deflected septum.	95	62″	4700	7000	13·5	518	1·5	20	Evacuated to England for treatment.
12. P. J. C.	450 hrs., Scouts. Rather tired. Feels drowsy after 30 mins. above 18,000 ft. but otherwise does not mind altitude.	70	80″	4000	(3400)	11	(310)	?	?	Ventilating figure probably wrong due to a leaky valve. Evacuated to England for H.E.
13. E. A. C.	398 hrs., day bombers. Due for H. E. Rather tired. Average height only 15,000 ft.	150	63″	4500	10,000	22	450	2·2	48	Evacuated to England for rest and H.E.

14. J. R. C.	212 hrs., Scouts. To hospital for scabies. Rather tired.	95	63″	4750	7250	15	483	1·5	22	Treatment, then sick leave.
15. W. B. I.	213 hrs., Bristols, as observer. Rather tired. Due H. E.	70	45″	3600	6500	12	542	1·8	22	Evacuated to England for rest and H.E.
16. W. J. G.	300 hrs. Scouts. A little stale. Has signs of fatigue.	85	35″	3730	6450	10	615	1·65	17	Evacuated to England and recommended for Canadian leave.
17. C. M. H.	233 hrs., day bombers. Feels stale and has signs of considerable fatigue.	115	60″	4800	5625	11·5	487	1·17	14	Evacuated to England for rest and H.E.
18. W. C. L.	300 hrs. Scouts. Recent repeated vomiting due to Eustachian obstruction. Very tired in consequence.	60	29″	4200	7660	15	510	1·82	27	Evacuated to England for treatment of ears.
19. R. C.	46 hrs., day bombers. Very fatigued on landing. Considered by squadron as temperamentally unsuited to active-service flying.	80	64″	3400	5000	11	454	1·47	16	To duty on ground, temperamentally unfit.
20. S. H. H.	290 hrs., day bombers. Flying 15–20,000 ft. without oxygen. Recent headache. Very tired.	70	47″	3900	5250	5·5	955	1·35	8	Respiratory rate without tube 15 and very shallow. Evacuated to England for rest and H.E.
21. C. L. L.	550 hrs., Scouts. Rather sleepy at altitudes. Very tired.	65	27″	4500	8800	20·5	430	1·95	40	Evacuated to England for rest and H.E.
22. G. S.	110 hrs., day bombing. Cannot keep formation. Astigmatism. Tired after flying at 18,000 ft., but has no other symptoms. Tested Dreyer up to 24,000 ft. Very good.	110	57″	4900	7100	15·5	458	1·45	22	Proceed to [illegible] to instructor.

TABLE I. GOOD AT ALTITUDES *(continued)*

No. and Name.	*History.*	*Flack's Manometer.* *Max.*	*Duration at 40 mm.*	*Vital Capacity*	*Ventilation per minute.*	*Respiratory Rate.*	*Tidal Air.*	*V. M. V. C.*	*Factor.*	*Remarks.*
23. L. H. T.	170 hrs., Bristols. Recently crashed in flames. Sleeping badly since. Slight tremor.	95	50″	4750	10,500	12·5	840	2·21	28	Evacuated to England for rest and H.E.
24. C. R.	330 hrs. Long distance reconnaissance. Flying 18,000 ft. with oxygen, but has been fairly fit even when this has failed. Losing weight lately. Tired. Due for H. E.	70	58″	4300	7350	13·5	543	1·71	23	Evacuated to England for rest and H.E.
25. W. H. B.	273 hrs., Scouts. Quite fit at altitudes. Tired, with exaggerated reflexes and tremor.	115	54″	3550	6850	17·5	390	1·93	34	Evacuated to England for rest and H.E.
26. J. H. P.	620 hrs., Bristols. Recently slight sleepiness in the air. Highest flown, 20,000 ft.	75	55″	4600	5000	14·5	345	1·09	16	Evacuated to England for rest and H.E.
	AVERAGES	96	57·3″	4260	6970	14·1	523	1·55	24·1	
	Below Standard (minimum U-tube)	34·6%	15·4%	4%		15·4%		20%	24%	
	Below Average Standard U-tube	69·3%	38·5%							

Passing all tests, 46·2%.
Average number of hours flown, 240.

TABLE II. BAD AT ALTITUDES

No. and Name.	History	Flack's Manometer: Max.	Flack's Manometer: Duration at 40 mm.	Vital Capacity.	Ventilation per minute.	Respiratory Rate.	Tidal Air.	V. M / V. C.	Factor	Remarks.
1. R. L. T.	51 hrs. (1½ in France). Ill above 13,000 ft. Tachycardia and respiratory rate above 30 even in bed.	90	35"	?	11,550	44	2...	?	?	D.A.H. type. Excused to England.
2. F. R. G.	42 hrs. Scouts. Dizzy above 10,000 ft. Tested by Dreyer (38) rather bad. Cheyne-Stokes type.	170	48"	3200	9280	17	530	2.85	18	Quite [illegible] bad. To try again and [illegible] if necessary.
3. C. R. B.	240 hrs. Scouts. Cannot stand over 10,000 ft. Very bad by Dreyer's test. Excessive respiratory type (Dreyer test 36).	30	20" (to 20 mm. only)	2800	11,500	155	745	4.2	66	Fairly below 10,000 ft.
4. F. F.	700 hrs. flying. Corps work. Tired. Highest flown 16,000, feels very ill above 15,000 ft.	110	45"	3900	8750	20.5	440	2.2	46	Evacuated to England for H.E.
5. H. J. E.	597 hrs. Scouts. Recently sleepiness and dyspnoea at 18,000 ft. Not really comfortable above 10,000 ft. now. Very tired.	80	40"	4000	10,550	16.5	640	2.6	43	Evacuated to England and recommended for Ventilation Test.
6. N. M. S.	145 hrs. (25 in France). Faintness above 14,000 ft. Scouts. Tested by tube method and found to be rather bad.	75	45"	4050	6250	18	345	1.5	27	Not very [illegible]. Physical training and [illegible] recommended.

TABLE II. BAD AT ALTITUDES *(continued)*

No. and Name.	*History.*	*Black's Maximum.* Max.	*Duration at 40 mm.*	*Vital Capacity.*	*Ventilation per minute.*	*Respiratory Rate.*	*Tidal Air.*	*V. M. U. C.*	*Factor.*	*Remarks.*
7. C. F. C.	Scouts. Hours uncertain. Age 38. Abdominal pain at high altitudes. (Query, 100 hrs.)	130	45	4900	11,350	14·5	785	2·3	33	Only moderately bad. Returned to duty at own request.
8. C. P. T.	100 hrs. Highest flown 6000 ft. Tested by tube method, not at all good. Subnormal vascular response with fall of blood pressure.	?	?	3725	7750	28	276	2·1	59	Respiratory rate with out tube 16.
9. J. A. B.	130 hrs. (20 in France). Fainted in air at 12,000 ft. On day bombers. Only 20 hrs. of high flying. Tested tube method. Subnormal vascular response and Cheyne-Stokes respiration.	65	30″	3700	8100	15·5	520	2·9	45	To cease flying. Temperamentally unfit
10. L. P. K.	140 hrs. (20 in France). Day bombing. Fainted at 10,000 ft. in the air. Tested tube method 14,000 ft. Bad periodic breathing, pain in praecordium, and commencing heart failure.	60	30″	3850	6750	12	563	1·75	21	To fly night bombers only. Very good type.
11. C. P.	20 hrs. as observer day bombers. Headache above 10,000 ft. with impairment of judgement.	50	27″	3325	12,250	26	480	3·7	96	To cease flying. Temperamentally unfit.
12. R. N. W.	50 hrs (none on active service). Felt faint at 5000 ft., and was ill on landing. Has fainted on the ground. Good type but signs of cardio-vascular debility.	40	20″	3300	5600	14	400	1·7	24	To cease flying. Temperamentally unfit.
13. A. M.	170 hrs day bombing. Above 15,000 ft. feels sick and giddy, has vomited. Headache.	120	45″	4000	9000	23	390	2·25	52	To do ground work.

14. J. W.	100 hrs. (30 in France) day bombing. Feels bad above 9000 ft, and cannot get his breath. Tested by Dreyer method. Very bad. Periodic respiration (Dreyer 40).	50	33″	4400	9100	24	380	2·1	50	Evacuated to England. Quite unfit for high flying.
15. W. C. F.	54 hrs. (3 in France). Feels ill even at 9,000 ft. Dreyer test (41) showed he was very bad with excessive respiratory response and dyspnœa.	55	37″	3300	6200 ↓ (11,250)	26 ↓ (34)	230 ↓ (331)	1·9 ↓ (3·4	49 ↓ (115)	Big increase in ventilation during test. Respiration very unstable. Evacuated to England being unfit for general service.
16. J. H. G.	100 hrs. (50 in France) on day bombers. Highest flown 14,000 ft. Feeling ill lately and fainted in air before admission to hospital. Tested by Dreyer methods very bad, with subnormal response (Dreyer 43).	70	60″	3725	12,600	20	630	3·4	68	To fly night bombers only.
17. A. M. B.	80 hrs. (10 in France). Giddy above 16,000 ft.	50	29″ (25 mm. only)	3200	5500	30	183	1·7	51	Ventilation figure uncertain. Little short pulling respirations. Respiration at rest 22 without tube. Board of P.U.F.* Fit for general service.
18. W. H. G.	99 hrs. (5 in France). Feels dizzy if above 13,000 ft. Scouts. Tested by Dreyer (45). Fainted after having very periodic breathing.	105	65″	4300	7150	14	510	1·7	24	Evacuated to England for treatment of Cheyne-Stokes respiration, which he also had. No use for scouts.

* P.U.F. indicates permanently unfit for flying on medical grounds.

TABLE II. BAD AT ALTITUDES (*continued*)

No. and Name.	*History.*	*Flack's Manometer.*		*Vital Capacity.*	*Ventilation per minute.*	*Respiratory Rate.*	*Tidal Air.*	*V. M. V. C*	*Factor.*	*Remarks.*
		Max	*Duration at 40 mm.*							
19. A. S. M.	141 hrs. (50 in France). Scouts. Dyspnoea above 11,000 ft. Tested by Dreyer (25). Later developed height psychosis.	120	53″	4700	6610	12·5	527	1·4	18	Transferred to infantry at his own request.
20. N. M. D.	100 hrs. Observer on Bristols. Short of breath above 18,000 ft. Had rapid breathing and gasping for breath. This got worse until he could not go into the air at all.	95	35″	3280	7100	23	308	2·2	1	Has done six weeks' work on the ground and improved. To do three months' more ground work. Useless for high flying.
21. J. K. G.	60 hrs. (5 in France). Scouts. Never higher than 9500 ft. when he feels uncomfortable. Tested on Dreyer, considerable distress with periodic breathing at 16,000 ft. (Dreyer 46).	75	45″	3600	7316	15	490	2·04	31	To fly below 10,000 ft. To seaplanes.
22. L. D. R.	78 hrs. Nil in France. Scouts. Bad crash when training. Giddy above 5000 ft. Tested Dreyer 16,000 ft. not good. Has low diastolic pressure.	70	40″	3750	4750	10	475	1·25	13	Ventilation figures probably inaccurate with leaking valve. Evacuated to England
23. J. B. P.	40 hrs. Nil in France. Crashed when training. Dizzy above 10,000 ft. Tested by Dreyer (47) to 16,000 ft. Periodic breathing and bad response.	80	48″	4600	5375	11	488	1·15	13	Disability probably largely temperamental. Periodic type of bad response. To duty on ground for temperamental reasons.

24. G. H. D.	19 hrs. Observer on day bombers. Long period with infantry with concussion. Feels faint at 13,000 ft. Tested by Dreyer to 16,000 ft. Bad with periodic breathing.	70	40″	4100	10,250	23	446	2·5	57	To fly below 4000 ft.
25. J. C. W.	106 hrs. day bombers. Headache and dizziness if doing a long period above 15,000 ft.	85	22″	3750	7600	14·5	524	2·02	29	Only moderately bad at altitudes. To fly night bombers.
26. S. S. G.	17 hrs. as observer on day bombers. Tested Dreyer to 18,000 ft. Increase to respiratory rate to 52 with headache and sleepiness.	130	50″	3100	9900	28	353	3·2	90	Very bad at present. Evacuated to England for physical training and later change to low flying machines.
27. W. B.	110 hrs. day bombing. Cannot fly straight above 10,000 ft. Feels very sleepy and observers complain that he is inefficient at these altitudes.	75	37″	3700	10,620	15·5	688	2·87	45	To duty on night bombers only
28. W. J. B.	85 hrs. (5 in France) day bombing. Feels ill over 5000 ft. D. A. H. type of pulse.	50	23″	3500	9500	38	250	2·71	103	Respiratory rate without tube 22. Passed P.U.F.
	AVERAGES	81·8	38·7″	3770	8500	20·1	452	2·3	46·3	
	Below Standard (minimum U-tube)	55·5%	48·2%	29·6%		57·2%		64·3%	71·5%	
	Below Average Standard U-tube	74·1%	89%							

Passing all Tests, 10·7%.

Average number of hours flown, 131.

TABLE III. UNCERTAIN AT ALTITUDES

No. and Name.	*History.*	*Flack's Manometer.* *Max.*	*Duration at 40 mm.*	*Vital Capacity*	*Ventilation per minute.*	*Respiratory Rate.*	*Tidal Air.*	*V. M. V. C.*	*Factor.*	*Remarks*
1. A. H. R.	90 hrs. night bombing. Hospital for influenza. Has never been to high altitudes.	140	45″	4650	8600	7	1255	1·85	13	Respiration much slowed by tubes and valve. Sick leave.
2. S. W. K.	120 hrs. Observer on Bristols. Good, but recently tired and has eye trouble, apparently due to fatigue.	120	43″	3900	10,800	21	510	·2	67	Evacuated to England for rest and H.E.
3. W. H.	462 hrs. Corps work. No high flying. Tired and due for H.E. Age 40.	120	44″	3500	8920	11	812	2·55	28	Evacuated to England for rest and H.E.
4. R. J. W.	64 hrs. (none in France). Has never been above 6000 ft. Feels lonely. Height Psychosis. Wants to do low strafing.	75	32″	3650	7060	13	538	1·9	25	To medical flight.
5. J. E. B.	197 hrs. day bombing. Continuous headache after 47 hrs. high flying. No other cause found.	85	24″	3700	7800	20	390	2·1	2	To do ground work at present.
6. E. B. O. B.	184 hrs. (24 in France). Short of breath and giddy above 10,000 ft. Bristols. Tested on Dreyer (44) to 20,000 ft. and was very fit but had very rapid respiration. Is very unlikely to remain good at high altitudes.	115	58″	3600	13,250	22	615	3·75	82	Though at present fairly fit not a type suited to high flying. Discharged fit for duty, now working as ferry pilot. Very excitable subject.

7. A. E. H.	210 hrs. on day bombers. Always flies using oxygen and has a very bad headache if this fails. Now very tired.	100	17″	4400	9100	13	700	2·1	27	Probably fairly good at height but not better than that. Evacuated to England for rest and H.E.
8. P. H. D.	194 hrs. as observer in Corps work. No high flying. Due for H.E. Tired.	75	45″	4500	7500	12	625	1·7	20	Evacuated to England for rest and H.E.
9. D. S. G.	25 hrs. on balloons. Old depressed fracture of skull without operation. Symptoms of traumatic neurasthenia. Headache. Accident 18 months before examination.	55	33″	3250	6250	11	580	1·9	21	Fast unstable pulse of D.A.H. type. Evacuated to England for discharge from Army.
10. V. G. C.	75 hrs. Scouts. Recent severe concussion. Has been to 18,000 ft. and been quite fit. Headaches since crash.	75	48″	3100	10,750	2	450	3·5	84	Unstable pulse of mild D.A.H. type. Evacuated to England.
11. A. F. W.	200 hrs. Observer in Corps work and night bombing. Has never been to high altitudes. Due H.E.	300	96″	4000	12,500	16	735	3·1	50	Evacuated to England for H.E.
12. D. W. F.	580 hrs. Scouts. Patrols at 16,000 ft. make him sleepy. Recently has repeatedly vomited in the air. Very tired.	84	38″	4575	10,375	14	740	2·3	32	Evacuated to England for rest and H.E.
13. J. E. B.	70 hrs flying. Dyspnœa and vomiting above 10,000 ft. On day bombing. Tested by tube method and found fairly good. Has deflected septum and some ear trouble.	100	50″	3300	6250	9·6	650	1·9	18	Sick to oxygen with ear trouble work ceases. To medical flight.

TABLE III. UNCERTAIN AT ALTITUDES *(continued)*

No. and Name.	*History.*	*Flack's Manometer*		*Vital Capacity.*	*Ventilation per minute.*	*Respiratory Rate*	*Tidal Air.*	*V. M. V. C.*	*Factor.*	*Remarks.*
		Max.	*Duration at 40 mm.*							
14. H. C. B.	140 hrs. day bombing. Always uses oxygen. Once did a 3 hr. show at 18,000 ft without oxygen. Had to go to bed afterwards.	95	60″	3900	7600	19	400	1·95	37	In hospital following a crash. Probably would never last at high altitudes without oxygen.
15. C. N.	90 hrs. (10 in France). Day bombing. Felt queer at 16,000 ft	80	47″	4200	6250	15·5	405	1·4	22	Immature youth, with low blood pressure. To fly, using oxygen.
16. W.	M. O	100	60″	3500	9000	12	750	2·57	31	
17. A. D. M.	113 hrs. (2 in France). Faints at the sight of blood. Corps work. Highest flown 13,000. Not very fit at this altitude.	70	57″	3950	5250	11·5	362	1·35	16	To duty.
18. C. C. W.	330 hrs. night bombing. Rather tired. Would like to do work on scouts.	60	25″	3750	5000	17	295	1·33	23	Evacuated to England for rest and H.E.
19. C. W.	118 hrs. Bristols. Sleeping badly last three weeks of his time, then wounded a month before examination. No flying since he was wounded	70	35″	3650	9000	25	360	2·46	61	Evacuated to England for rest and H.E. Probably would never stand much high flying.
	AVERAGES	100·8	47·4	3850	8500	15·4	588	2·26	36·8	
	Below Standard (minimum U-tube)	36·8%	31·6%	15·8%		36·8%		47·3%	47·3%	
	Below Average Standard U-tube	73·7%	68·4%							

Passing all tests, 26·3%.

Average number of hours flown, 175.

(80 mm.) and 15·4 per cent. below the minimum standard of 40 mm. for the fatigue test, a low percentage considering the number of hours flown and the resulting fatigue.

On the other hand, of the bad type 55·5 per cent. are below the minimum standard expiratory force, and 48·2 per cent. below the minimum standard for the fatigue test, while in the uncertain group 36·8 per cent. are below in the former, and 31·6 per cent. in the latter test.

The low figures obtained in the bad types even after very little flying may perhaps be due to their flying experiences: some of these patients have fainted in the air, and such experiences seem to reduce the vitality of the individual to a low level. Thus one officer with 67 hours flying who had fainted in the air on his last trip was only able to blow the manometer to 45 mm. five days later, while after ten days he could blow it to 55 mm., after eighteen 75 mm., and after 22 days 90 mm., and in the same time he improved his maintenance of the mercury at 40 mm. from 30″ to 38″. It is, therefore, unlikely that any excessively low figures would be found in these officers before they had experienced fatigue or symptoms due to high altitudes. None the less those giving results much above the minimum standards would probably fair better on high-flying machines than those barely passing these standards, and there can be little doubt that these tests are of value in the selection of men for flying at high altitudes, particularly if the average standards for the tests be taken and not the minimum. (Average standards 105 mm. and 52″.)

Vital Capacity. A minimum vital capacity of 3,000 c.c. has now been fixed by the Commissions Board. This standard appears to take no account of the size of the individual. For high flying it is suggested that no one with a capacity below 3,400 c.c. be accepted unless he can hold his breath for more than 45 secs. It will be noticed that in the good type there is included one excellent scout pilot (Table I, 9), with a vital capacity of 3,200 c.c., he being a very small man. It will be seen, however, that he can hold his breath 50 secs. This officer has thirty-nine enemy machines to his credit. Taken as a whole, however, only 4 per cent. of the good type are below the 3,400 c.c. standard, and the average value is 4,260 c.c., while in the bad type 29·6 per cent. are below this standard, and the average is 3,770. As before, the uncertain group takes an intermediate place with an average of 3,850 c.c. The vital capacity test is therefore also valuable, especially if considered in relationship with the size of the individual, or better with his normal air consumption per minute.

The ventilation per minute shows a higher figure for the bad type than for the good—a consumption of 8,500 c.c. as against 6,970 c.c., and this seems to be partly dependent on the existence of a fast shallow respiration, but not entirely so. Others have shown how a high-air consumption is found associated with the tachycardia in a D.A.H. condition, and a similar large consumption of air is found in the thin anxious type of individual. In the tired pilot who is beginning to be nervous, to be tremulous, to have exaggerated reflexes and to sleep badly, a history of loss of weight

is quite common, and in these cases also the air consumption appears to be raised quite apart from any increase in the respiratory rate. A good instance may be seen in Table I, 9 and 10, a case which also serves to illustrate the changes seen with the U-tube manometer as the result of fatigue. It appears that these fatigue results, though aggravated by high altitude flying, are more due to the nervous strain of fighting than to flying itself (cf. cases included in Table III).

The respiratory rate is 14·1 per minute in the good type, 20·1 in the bad, and 15·4 in those whose behaviour at altitudes is uncertain. If a standard of 16 per minute is taken then 23 per cent. have a rate faster than this in the good, 57·2 per cent. in the bad, and 36·8 per cent. in the uncertain type. A slow respiration is therefore a good sign, and if it is still further slowed on meeting slight resistance to expiration so much the better. The respiration rate was rather unusually high in the patients recorded in the Table I, 8 and 9 considering their flying history, but they had both recently had influenza, and it is possible that this disease tends to quicken the respiratory rate in a way similar to its effect on the pulse-rate.

The tidal air is smaller in the bad types than in the good, since their respiration is generally quicker and shallower, but many very small tidal airs are also found in the good types in whom the ventilation figure is low, and in this case, when associated with a slow respiration rate, it is no disadvantage.

The ratio of the ventilation per minute to vital capacity seems of considerable importance, and this has been expressed by recording the value $\frac{\text{ventilation per minute}}{\text{vital capacity}}$. It is obvious that if an individual requires a large amount of air per minute he will require a large vital capacity also, if he is to stand high altitudes well, and this has been found to be the case. In the good type this ratio has an average value of 1·55, in the bad 2·3, and in the uncertain group of 2·26; in the first class only 20 per cent. have a value above 2·0, in the second 64·3 per cent., and in the last 47·3 per cent. It would appear, therefore, that the value of vital capacity tests is much greater, if the vital capacity be judged according to the relationship it bears to the air consumption of the individual.

Lastly, an *artificial factor* has been deduced which seems to give some idea of the ability of the individual to stand high altitudes from the respiratory point of view. Since a slow respiration, a large vital capacity, and a low ventilation rate all indicate an increased reserve for use at high altitudes, this factor consists simply of the value $\frac{\text{respiratory rate} \times \text{ventilation per minute}}{\text{vital capacity}}$, and a low figure indicates a good type. A figure of 30 has been taken as the standard, those above this being relatively bad.

It will be seen that the average figure for the good type is 24·1, for the bad 46·3, and for the uncertain 36·8. Similarly, 24 per cent. of the good type fall above 30, 71·5 per cent. of the bad, and 47·3 per cent. of the uncertain. This factor seems, therefore, to be even more effective at selecting those bad at altitudes than the U-tube manometer, and though it too may be influenced by fatigue, it is

probably more constant in any individual than the results obtained with the U-tube fatigue test.

If, now, the results with the U-manometer and this factor be alone considered, it will be seen that in the good type, containing many tired men (the average hours flown being 240), 46·2 per cent. pass all three tests, 57·7 per cent. pass both U-tube minimum standards, and 76 per cent. pass on the factor standard. In the bad type (the average number of hours being 131) only 10·7 per cent. pass all tests, 33·3 per cent. pass both U-tube minimum standards, and 28·5 per cent. pass the factor standard. In those uncertain at altitudes (average number of hours flown being 175), 26·3 per cent. pass all three tests, 52·7 per cent. pass both U-tube minimum tests, and 52·7 per cent. pass the factor standard. It is clear that the factor standard often picks out cases which pass the U-tube tests (minimum standard) and vice versa, but the factor seems to be more efficacious at picking out those bad at altitudes than the two manometer tests combined when the minimum standards are employed.

The average standards of the U-tube test are much above the level attained by most of those in Group II, 74·1 per cent. being below the maximum average standard and 89 per cent. below the average figure for fatigue. Yet this test shows such variations from day to day, according to the temporary physical condition of the patient, that it is unlikely to prove as valuable as simple respiratory measurements in the selection of airmen for high flying. In this connexion it is noticeable what a large proportion of the good type, when they are tired, also fall below these average standards.

C. The Value of the Methods employed.

The U-manometer test as designed by Flack has proved its value as a test of physical fitness of the individual at the time of examination, and for this purpose the other tests here described have little importance. No very definite conclusions can be drawn from figures obtained in pilots in various stages of exhaustion, but it is probable that by some such examination of the vital capacity, ventilation per minute, and respiratory rate, it should be possible to pick out those airmen whose physique makes them peculiarly suitable for high altitude work, especially as a large percentage of pilots are able to stand altitudes fairly well. It would be wise to take into consideration the U-tube results at the same time, but it should be recognized that of the two tests the U-tube tests are probably less important. Even if these tests were employed before training pilots on high-flying machines, a certain number would still eventually be found unable to stand the high altitudes, since cardio-vascular failure may also occur, as well as a periodic type of respiration sufficiently severe to cause inefficiency. But, if the effects of fatigue be allowed for in the results here recorded, it seems probable that the wasteful training of men unsuited for high flying might be avoided in from 70 per cent. to 80 per cent. of the cases, if these simple respiratory tests were employed before the

men were trained for this type of work, and, if those who showed low diastolic pressures were also not allowed to attempt flying at high altitudes, any such wasteful training might perhaps be reduced still further.

D. Conclusions.

(1) That men with a high vital capacity, a low consumption of air per minute, and a slow respiratory rate, have a greater reserve than others to enable them to withstand high altitudes.

(2) That this extra reserve may be represented roughly by a factor $\frac{\text{respiration rate} \times \text{ventilation per minute}}{\text{vital capacity}}$, and that any figure thus obtained below 30 is good, and above this poor.

(3) That additional evidence of good types of physique for high altitude flying may be obtained from the results with the U-tube manometer tests, but that these are less important from this point of view. They are more affected by fatigue than the former results, and especially by the fatigue of great nervous strain, so that their value in measuring temporary exhaustion is very great.

(4) That by the employment of these simple tests early in the training of a pilot or observer, it might be possible to select those likely to be able to stand altitude well, and to abolish 70 per cent. to 80 per cent. of the failures at altitudes that now occur, so eliminating much wasteful and expensive training.

Note.—I am indebted to Mrs. Briscoe for a personal communication, before these observations were commenced, in which she pointed out that the oxygen consumption per minute was often above normal in pilots who were hospital patients. Her observations, though viewed from a different aspect, would appear to agree with the rough empirical tests here reported.

Appendix.

In revising this paper for republication reference may be made to the recent interesting paper by Dreyer (1) in which he correlates vital capacity with weight and other measurements. No calculations of this character are possible with the material here collected, since no means were available for determining the exact weight of the subjects examined. Since the metabolism has been shown to bear a similar relation to the surface area (2), the comparison of vital capacity with the ventilation rate is a similar process. For the purpose of estimating the capacity of an individual to withstand high altitudes I consider the method here adopted the more useful, since there is no guarantee, especially under war conditions (cf. Mrs. Briscoe's results), that the metabolism is at a normal level for the surface area of the individual, while the relationship of the vital capacity to the work it has to do remains the factor of primary importance. That big variations in the vital capacity occur with variations in physical fitness, as suggested by Dreyer's paper, I can confirm in that my own vital capacity has varied between 5,375 c.c. (Table I. 1) and 4,500 c.c. during the last 18 months.

References.

(1) G. Dreyer, *Lancet* Aug. 9, 1919, p. 227.
(2) Atwater and Benedict, 1903. J. C. Ach and E. Du Bois, *Cornell Univ. Med. Bulletin*, vii, 1918

10.—OBSERVATIONS ON THE RESPIRATION OF AIRMEN

BY

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(Received October 20th, 1918.)

THESE observations on the respiration of airmen admitted to hospital for various causes were carried out by means of the apparatus devised by Douglas for studying the respiratory exchange.

The object of the investigation was to see if any marked deviation from the normal could be detected in the respiratory mechanism of airmen suffering from one form or other of flying disability.

A. OXYGEN METABOLISM.

The apparatus for determining the total respiratory exchange consists of a large rubber canvas-covered bag, containing 30 to 40 litres when moderately distended. This bag is connected by a rubber tube of large calibre with a mask, which covers the mouth and nose, and which is provided with inspiratory and expiratory valves. Between the mask and the bag is a three-way tap of large bore, so that the subject can breathe into the bag or into the open air at will. The subject sits comfortably in an arm-chair, with the mask pressed closely over the nose and mouth. The bag is fixed behind the chair, so that he is unable to see the amount of distension. With each breath he takes in fresh air through the inspiratory valve and all the expired air passes out through the expiratory valve and tube. For the first two minutes the tap in the connecting tube is turned, so that the expired air passes out into the room, and when the patient is quite comfortable with the mask, the tap is turned, so that all the expired air passes into the bag. The expired air is collected over a timed period (3 to 5 minutes according to the amount of lung ventilation) and the rate of respiration noted. At the end of the timed period, the tap is turned and the rubber tube disconnected from the expiratory valve and attached to a gas meter. While the air is being passed through the meter, a sample is taken through a small by-pass connected with the bag. The composition of the air in the sample is analysed, and this analysis gives the percentages of oxygen and carbon dioxide in the expired air. The amount of oxygen used by the individual is calculated from the difference in the percentages of oxygen in the inspired and expired air, and the amount of air which passes through the lungs per minute.

In order to compare subjects of varying weight, the actual amount of oxygen consumed has been divided by the weight of the individual in kilograms and the figure thus obtained, i.e. the amount of oxygen consumed per minute per kilogram has been taken as the standard of comparison.

As far as possible all the patients were examined under the same conditions. It was not possible to carry out the investigation under conditions of complete rest, but the examination was made early in the day, between 10 and 12 a.m., and after sitting comfortably at rest in an arm-chair for about a quarter of an hour.

As individuals vary from day to day in the rate of oxygen usage, the first cases were examined at some length, to get an idea of the amount of variation. In some patients the rate from day to day was very constant, in others the variation was considerable, and seemed to be independent of small changes in temperature and pressure. In Table I the figures obtained in two cases are given in detail; in No. 1 the rate of consumption is practically the same on three different days, in No. 2 the figure varies by about 14 per cent. In the case of No. 1, the room temperature varied by 6° F., and in the case of No. 2 by 1° F.

The results obtained in a series of 30 pilots and observers are given in Table II. Where more than one observation has been made, average results are given. The cases are given in the table in the order in which they were examined, without any kind of selection. They include some fairly fit men on the point of being discharged from hospital, and some cases with marked nervous symptoms. The figures given may be compared with those obtained from a series of controls (Table III). This series of controls includes four fit experienced airmen and eight flying cadets, just passed as fit by the Commissions Board. The patients were examined in the morning before they had left the hospital or taken any exercise; the controls all had to come in from outside the hospital, and the successful airmen had a motor drive from a neighbouring aerodrome. Under these conditions the rate of metabolism at rest should have been lower in the hospital patients than in the controls.

The average oxygen consumption (measured at room temperature) for the 12 controls is 4·7 c.c. per min. per kilo (minimum 3·9 c.c., maximum 5·3 c.c.), the average figure for the thirty patients is 5·1 c.c. per min. per kilo (minimum 4·4 c.c., maximum 6·1 c.c.). The majority of the patients showed definite symptoms of a nervous nature. If the cases (18 in number) classed clinically as 'neurasthenics' be taken separately, the average rate of oxygen consumption is 5·3 c.c. per min. per kilo, while the average rate in the remaining cases (12 in number) is 4·9 c.c. per min. per kilo. Taken as a whole the higher figures were obtained in 'nervy' patients of the jumpy restless type.

It is difficult to compare these figures with those obtained by other methods, as most of the results recorded refer to oxygen consumption at complete rest, i.e. lying down and with complete muscular relaxation.

Benedict gives the following figure as an average of daily estimations for 3 months on an athlete, at complete rest and on a regular

TABLE I

Name.	*Date.*	*Litres of air per min.*	*Breaths per min.*	*Vol. of each breath, in c.c.*	*Measured moist and at preceding barometric pressures.*						*Dead space, c.c.c.*
					% O_2 expired air.	*% CO_2 expired air.*	*Alveolar CO_2 %*	*O_2 consumed per min. in c.c.*	*CO_2 expired per min. in c.c.*	*O_2 consumed per min. per kilo., in c.c.*	
Lt. G. :											
Weight, 64·3 kg.	27/2/18	6·4	12·5	516	16·33	3·85	5·77	290	246	4·6	119
Hours flying, 160.	1/3/18	7·85	16·5	478	17·01	3·57	5·55	308	280	4·7	121
	2/3/18	7·5	16	468	16·97	3·54	5·66	300	265	4·6	123
Lt. B. :											
Weight, 63·8 kg.	6/3/18	6·25	18	347	16·44	3·77	6·07	283	235	4·4	64
Hours flying, 100.	7/3/18	7·02	19	369	16·38	3·69	6·63	321	259	5·0	110
	9/3/18	6·9	18·5	372	16·47	3·75	6·09	310	258	4·8	91

TABLE II

Name.	Hours flying.	Weight in kg.	No. of observations.	Litres of air per min.	*Measured moist at prevailing baro. pressures.* % O_2 in expired air.	% CO_2 in expired air.	O_2 consumed per min. in c.c.	CO_2 expired per min. in c.c.	O_2 consumed per min. per kilo, in c.c.
Lt. A. H. W.	45	73·0	4	8·6	16·31	4·09	398	351	5·4
Lt. F. W.	13	54·3	5	6·1	16·53	4·01	270	245	4·9
Lt. W. D.	100	67·0	5	5·3	15·61	4·83	294	261	4·4
Lt. E. M. C.	6	66·2	4	9·5	17·28	3·35	361	335	5·4
Lt. J. C.	160	68·4	3	8·2	16·97	3·26	328	267	4·8
Lt. A.	1,575	69·8	3	9·8	17·64	2·94	327	288	4·7
Lt. B.	100	55·3	3	8·0	17·02	3·48	314	277	5·7
Capt. S.		60·7	2	8·4	17·03	3·29	331	277	5·4
Lt. H.		63·8	1	8·2	16·9	3·38	330	277	5·1
Capt. H.	600	61·6	3	6·3	16·58	3·37	273	212	4·4
Lt. B.	100	63·8	3	6·7	16·43	3·73	304	250	4·7
Lt. A. G. G.	160	64·3	3	7·2	16·77	3·65	301	263	4·6
Lt. C.	167	53·5	3	8·0	17·45	3·51	283	280	5·2
Lt. C.	50	56·2	2	6·9	17·16	3·26	262	230	4·6
Lt. M.		65·2	1	6·6	16·56	3·66	291	241	4·5
Capt. L.	180	69·7	4	8·8	16·87	3·56	357	313	5·1
Lt. V.	200	56·2	3	9·6	17·3	3·5	348	336	6·1
Lt. M.	400	62·0	2	5·9	16·02	4·04	292	240	4·7
Lt. W. J. W.	300	55·8	4	8·4	17·26	2·8	308	235	5·5
Lt. B.	13	67·1	2	9·6	16·73	3·36	403	322	6·0
Lt. G. H. B.	27	52·1	1	6·5	16·4	3·4	298	223	5·7
Lt. C.	18	76·2	1	9·1	16·24	3·22	429	295	5·6
Lt. L.	100	57·1	1	7·0	16·94	3·07	282	217	4·9
Lt. C.	400	64·7	2	8·4	17·37	2·87	299	241	4·6
Lt. D	500	69·7	1	6·2	14·92	3·89	375	243	5·3
Lt. R	200	63·4	1	8·3	17·2	2·69	309	223	4·9
Lt. M.	55	59·8	1	7·5	16·35	3·9	349	295	5·8
Lt. C.	30	61·6	1	6·6	16·04	3·95	322	260	5·2
Lt. N.	360	57·5	1	5·7	16·18	3·41	271	195	4·7
Lt. F. A. G.	73	58·4	1	6·8	16·58	2·95	298	203	5·1
					Average	..	..	..	5·1

TABLE III. CONTROLS

	Name.	Hours flying	Weight in kg.	No. of observations.	Litres of air per min	*Measured moist at prevailing baro. pressures.* % O_2 in expired air.	% CO_2 expired air.	O_2 consumed per min. in c.c.	CO_2 expired per min. in c.c.	O_2 consumed per min. per kilo, in c.c
	Capt. B.	1,000	67·9	1	8·1	17·05	3·36	317	272	4·6
	Lt. W.	600	57·17	1	8·3	17·42	2·90	291	240	5·0
	Lt. C.	600	71·66	1	9·3	16·96	3·91	369	363	5·1
	Capt. K.	600	70·76	1	9·39	17·04	3·56	361	339	5·1
	A. H. C.		56·2	1	7·8	17·18	2·77	292	216	5·1
Flying cadets	R. C.		72·1	1	7·5	16·47	3·4	334	255	4·6
	Lt. E.		61·6	1	6·18	16·51	3·07	273	189	4·4
	L. G. M.		67·0	1	6·8	15·92	3·85	344	264	5·1
	J. F. P.		65·6	1	8·8	17·56	2·84	296	249	4·5
	J. S.		67·0	1	7·6	17·49	2·73	261	207	3·9
	R. B. D. C.		68·9	1	8·8	16·75	3·41	367	302	5·3
	A. S.		61·0	1	7·8	17·17	3·04	293	237	4·7
						Average	..	..	..	4·7

diet, 3·6 c.c. at S. T. P.) per min. per kilo—minimum 3·4 c.c., maximum 3·9 c.c.

The figure given by Geppert for a man at rest is 264 c.c. at S. T. P.) of oxygen per hour and kilograms. This amount measured at 15° C., 760 mm. would work out at 4·6 c.c. per min. per kilo.

Douglas, using the bag method described above, gives figures which would amount to 3·9 c.c. per min. per kilo at room temperature for a man at rest (lying) and 5·3 c.c. per min. per kilo for rest (standing). The figure for rest (sitting) would lie between these two.

Martin Flack, by the same method as Douglas, gives an average figure of 4·7 c.c. per min. per kilo (measured at room temperature) for rest after sitting quietly in an arm-chair for half an hour.

The figures given indicate a slight but definite rise in the oxygen consumption of patients suffering from one form or other of flying disability. A man weighing 60 kilo will use 15 litres of oxygen per hour at 4·4 c.c. per min. per kilo, while a man of equal weight will use 21 litres of oxygen at 6·1 c.c. per min. per kilo. This difference is not likely to be less, and is probably more, when the muscles are used at high altitudes, and the man with an extravagant resting metabolism is almost certain to be at a disadvantage in a rarefied atmosphere.

Prolonged flying in itself does not appear to produce a rise in the rate of oxygen consumption while at rest. If the patients in Table II are divided into two groups, in which *(a)* the rate of oxygen consumption is between 4·4 c.c. and 5·1 c.c. per min. and *(b)* the rate is above 5·1 c.c. per min., it will be seen that the average number of hours flying is just under 300 in the first group, and just over 120 in the second.

It is worthy of note that, out of six cases giving a history of concussion, five are on the high side, the rate varying between 5·1 c.c. and 6·0 c.c. per min. per kilo.

B. The Rate and Depth of Respiration.

The rate and depth of respiration in a series of patients were determined by the Douglas bag method, as described in Section A; and the results compared with those obtained from a series of fit men examined under the same conditions.

The results are given in Tables IV and V.

The Rate of Respiration.

The average figure for 37 patients is 18·4 per min., the lowest individual figure being 7 per min., and the highest 29·4 per min. The average figure for 16 fit men is 15·2 per min., the lowest 7·3 per min., and the highest 22 per min.

The Volume of Air Breathed.

The average volume of air breathed is practically the same in both series, 7·7 litres per min. in patients and 7·9 litres per min. in the fit men.

TABLE IV. PATIENTS

Name.	*Hours flying.*	*No. of observations.*	*No. of breaths per min.*	*Litres of air per min.*	*Av. vol. of each breath in c.c.*	*Alveolar CO_2 %*	*Dead space, in c.c.*
Lt. W.	45	4	14·3	8·6	607	5·98	139
Lt. E. M. C.	6	4	21·4	9·5	443	5·73	125
Lt. W.	13	5	15·0	6·16	413	5·93	81
Lt. D	100	5	7·5	5·3	707	5·42	
Lt. C.	160	3	19·5	8·25	423	5·27	110
Lt. A.	1,575	3	24·0	9·8	408	5·76	147
Lt. B.	100	4	21·2	7·8	367	6·01	126
Capt. S.	—	2	21·0	8·4	400	5·76	145
Lt. H.		1	19·0	8·2	430	—	
Capt. H.	600	3	16·0	6·3	393	5·05	90
Lt. B.	100	3	18·5	6·7	262	6·26	88
Lt. R.		1	16·0	9·6	600	—	
Lt. G.	160	3	15·0	7·2	480	5·71	120
Lt. C.	167	2	15·0	8·1	540	5·5	138
Lt. C.	50	2	16·0	6·9	434	5·5	141
Lt. M.	—	1	12·0	6·6	550	5·28	116
Capt. L.	180	3	21·3	8·8	410	5·95	112
Lt. V.	200	3	16·0	9·6	600	5·65	193
Lt. M.	400	2	12·5	5·9	472	5·83	94
Lt. W.	300	4	29·4	8·4	285	5·67	83
Lt. B.	13	2	18·5	9·6	520	5·18	129
Lt. B.	27	2	15·5	7·0	450	5·39	100
Lt. C.	18	1	22·0	9·1	416	5·27	110
Capt. E.	400	1	16·6	9·3	560	5·72	165
Capt. McE.	255	1	26·6	8·4	316	5·25	93
Capt. B	440	1	17·2	7·5	439	5·59	94
Capt. C.	250	1	22·0	6·3	280	5·21	48
Lt. H.	60	1	35·0	9·1	262	—	
Lt. L.	100	1	17·7	7·0	400		
Lt. C.	400	1	28·3	8·2	290		
Maj. M.	1,000	1	19·0	7·3	386		
Lt. D.	500	1	7·0	6·26	890		
Lt. R.	200	1	27·0	8·3	310		
Lt. M.	55	1	12·0	7·58	630		
Lt. C.	30	1	11·0	6·6	600	—	—
Lt. N.	360	1	14·0	5·7	410	—	
Lt. G.	73	1	23·2	6·8	296	—	
Average			18·4	7·7	418	5·59	

TABLE V. CONTROLS

Name.	*Hours flying.*	*No. of observations.*	*No. of breaths per min.*	*Litres of air per min.*	*Av. vol. of each breath in c.c.*	*Alveolar CO_2 %*	*Dead space, in c.c.*
Capt. B.	1,000	1	18·0	8·1	450	5·4	117
St. W.	600	1	18·6	8·3	454	—	
St. C.	600	1	7·3	9·3	1,272	—	—
Capt. K.	600	1	15·0	9·39	626	—	—
A. H. C.		1	22·0	7·8	354	—	
R. C.		1	18·5	7·5	405	—	—
Lt. E.		1	14·0	6·1	445	—	—
W. A.		1	12·0	7·8	650		
L. G. M.	—	1	11·0	6·8	624	—	—
J. F. P.	—	1	19·0	8·8	463	—	
A. S.	—	1	17·0	7·8	460	—	
R. B. D. C.	—	1	19·0	8·8	466		
J. S.		1	18·0	7·6	422		
Surg. H.	10	4	11·5	7·0	610	5·6	132
Surg. S.	—	1	11·0	7·76	705	—	
Lt. P. J.	—	1	12·3	7·58	616	—	
Average			15·2	7·9	563		

The Depth of Respiration.

The average depth of respiration is obtained by dividing the volume of air breathed per minute by the number of respirations per minute.

The average figure for 37 patients is 418 c.c. and for the 16 controls 563 c.c. It will be noted that the number of quick shallow breathers among the patients is high; in ten out of 37, the average depth of respiration falls below 400 c.c., while in the controls, only one out of 16 falls below 400 c.c.

There is no obvious relationship between the depth and rate of respiration and the rate of oxygen consumption. The shallow breathers are distributed fairly evenly between the slighter and the more severe cases.

The Changes produced in Normal Respiration by Breathing through Valves.

It is obvious that a measurement of the depth and rate of respiration obtained by breathing through a mask and valves may not give a true index of normal quiet breathing.

After the series of measurements recorded in Tables IV and V had been completed the use of an enclosed spirometer[1] became available. By means of this instrument a graphic record is obtained of the respiration rate and the volume of air breathed.

A further group of 28 patients, very similar in type to the first group, was examined in the following manner. A record of normal quiet breathing was taken while the subject read a newspaper and paid no attention to his breathing. Then the mask from the Douglas bag apparatus was fitted over the face and the subject was asked to continue reading paying as little attention as possible to the respiration. The results obtained were somewhat varied, and are given in Table VI.

Breathing through the mask produced an average increase of depth of about 5 per cent., at the same time the average rate of respiration was slightly diminished. Individual variations were considerable. Considering the alterations in the respiratory rate first: in 6 cases the rate remained the same, in 7 cases the rate was quickened, in 15 cases the rate was slowed. Extreme variations are seen in case No. 8, where the rate slowed to 14 per min. when the mask was used, as against a normal rate of 22 per min., and in cases Nos. 25 and 26, where the rates quickened considerably with the mask, from 27 to 34 per min. in No. 25, from 16 to 23 per min. in No. 26.

Considering the alterations in the depth of respiration: in 5 cases the volume per breath remained unaltered, in 16 cases the breathing deepened, in 7 cases it became more shallow. Usually the volume varied by about 40 or 80 c.c., in case No. 8 the volume of each breath increased by 120 c.c. with the mask, and in case No. 21, the volume decreased by 120 c.c. (In the graphic record an excursion of 1 mm. represented a change of volume of 40 c.c.)

[1] Provided by the Air Inventions Committee to the design of Sir Horace Darwin, K.B.E.

TABLE VI

No.	Name.	Normal quiet breathing. Rate of Respiration per min.	Normal quiet breathing. Depth of Respiration c.c.	Breathing through Mask and Valves. Rate of Respiration per min.	Breathing through Mask and Valves. Depth of Respiration c.c.
1.	Lt. P.	16	440	15	480
2.	Lt. H.	18	640	16	560
3.	Capt. M.	14	480	12	560
4.	Lt. Y.	16	440	14	520
5.	Lt. G.	16	520	16	520
6.	Lt. B.	18	440	17	480
7.	Lt. A.	19	400	19	400
8.	Lt. E.	22	440	14	560
9.	Lt. K.	14	440	14	480
10.	Lt. L.	18	480	18	440
11.	Capt. C. K	21	360	17	440
12.	Lt. E.	18	480	20	480
13.	Lt. W.	14	560	18	520
14.	Lt. M.	16	360	14	400
15.	Lt. M.	14	440	16	480
16.	Sgt. McR.	20	360	20	360
17.	Lt. G.	22	300	24	320
18.	Lt. B.	27	440	26	470
19.	Capt. N.	18	420	16	420
20.	Capt. S.	21	320	23	380
21.	Lt. F.	17	480	14	600
22.	Lt. B.	20	360	18	440
23.	Lt. B.	25	320	23	400
24.	Capt. L.	13	600	13	520
25.	Lt. W.	27	300	34	240
26.	Lt. C.	16	400	23	320
27.	Cdt. M.	16	480	14	440
28.	Lt. A.	16	400	15	480
	Average	18·2	432	17·9	474

Three examples of the graphic records obtained are appended. In these tracings the down stroke represents inspiration and the up stroke expiration.

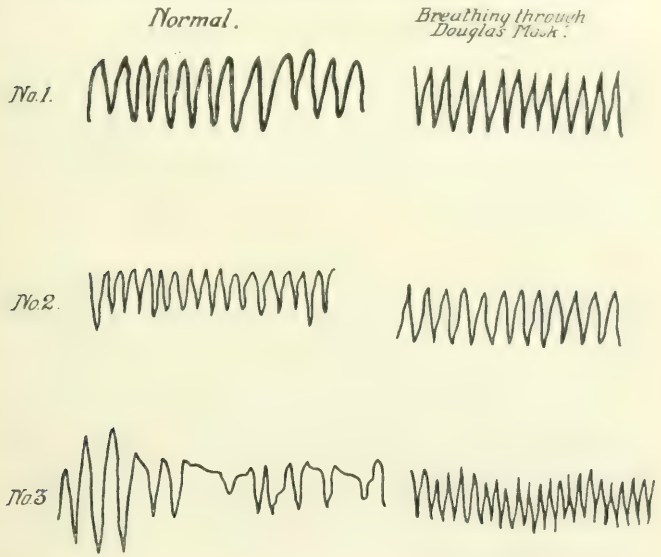
No. 1 is the tracing obtained from a fairly fit man; the slight expiratory pause is abolished when breathing through the mask. The deepening and slowing of respiration produced by the mask is illustrated in No. 2 tracing.

Patients with marked nervous symptoms usually give a very irregular tracing even when breathing quietly. In most of these cases breathing through the mask produced a more regular rhythm. An extreme example of this kind is seen in tracing No. 3. Here very irregular breathing at a moderately slow rate changes to a rapid regular rhythm. This patient is not included in Table VI, as the tracing of normal breathing is too irregular to measure satisfactorily.

Voluntary Variations in the Rate and Depth of Respiration.

It has been pointed out by Haldane and Priestley that the rate of breathing can be varied within wide limits, provided that the depth of breathing regulates itself, without any forcing or holding the breath. A normal man can breathe comfortably at 3 or 4 a minute or at 60 a minute if the depth of respiration is varied at

the same time. In the course of an investigation on the respiratory dead space at different depths of breathing, patients were asked to breathe as slowly as possible, without holding the breath or without making themselves feel uncomfortable. It was found that normal men and men suffering from a moderate degree of fatigue were able to breathe at 3 or 4 a minute without any discomfort. A certain number of patients seemed unable to regulate at will the rate of breathing. This failure occurred in patients in whom symptoms of a neurasthenic nature predominated. The difficulty appeared to lie in the regulation of the rate, rather than in the regulation of the depth of respiration. For instance, one patient who could only reduce the rate to 9 a minute was able to breathe at a depth of 1,700 c.c.,



a depth which would suffice a normal man breathing at the rate of 3 or 4 a minute.

C. The Alveolar Air.

In a number of cases the carbon dioxide in the alveolar air at rest was determined by the Haldane-Priestley method. Two samples were taken, one at the end of inspiration, the other at the end of expiration. The figures given in Table IV, column 6, represent in each case the mean of two such samples. Where more than one observation has been made, the average for each patient is given.

54 observations were made on 25 cases. The average figure was

5·59 per cent., the minimum was 4·8 per cent., and the maximum 6·63 per cent.

These figures may be compared with those given by Haldane and Fitzgerald :

	Mean.	*Minimum.*	*Maximum.*
Observations on 27 men	5·59%	4·72%	6·34%

Also with those given by Cook and Pembrey :

50 observations on 10 men :	5·57%	4·87%	6·11%

In this series of patients there is obviously no deviation from the normal, as far as the alveolar CO_2, when at rest, is concerned.

D. The Respiratory Dead Space.

The respiratory dead space at rest was determined by the method of Haldane and Douglas. The data required are : the average depth of an expiration (E) : the percentage of CO_2 in the expired air (e) by analysis of a sample of mixed air in the Douglas bag : the percentage of CO_2 in the alveolar air (a) : the dead space of the apparatus (d), i.e. the space between the valves and the face in the mask. The virtual dead space (D) is then calculated from these data by the formula :

$$D = E - E \times \frac{e}{a} - d.$$

The volume of the dead space in a normal man at rest, with an average depth of respiration, is usually given as lying between 128 c.c. and 158 c.c. Haldane has pointed out that the dead space varies with the depth of breathing, and that it may be increased by deepening the respiration.

The dead space, during quiet respiration at rest, was calculated in a number of patients and the figures are given in the last column of Table IV. Average figures are given where more than one observation has been made. It will be noted that while the majority of the figures fall within normal lines, some are on the low side, and on the whole the low figures are found in the shallow breathers.

In a few cases the dead space was calculated when the depth of breathing was varied voluntarily. The following figures illustrate the results obtained.

	Rate per min.	*Depth in c.c.*	*Dead Space in c.c.*
Natural breathing at rest	11·5	534	128
	13·5	511	136
Restricted breathing	30	293	80
Deep breathing	3	1,875	323

Summary.

In a series of pilots and observers, temporarily or permanently unfit for flying, the rate of metabolism at rest as indicated by the oxygen consumption has been found to be slightly but definitely

higher than in a series of fit men. In patients with marked nervous symptoms the rate was usually high.

Prolonged flying, *per se*, does not cause an increased rate of oxygen usage.

The frequent history of concussion in patients with a high rate of metabolism is noted.

The proportion of quick shallow breathers among the patients in this series was unduly high.

There is no evidence to show if the quickened shallow respiration was the result of flying stress, or whether it was present before the strain of flying began.

A restricted dead space was usually found in the shallow breathers.

Determination of the alveolar CO_2 showed no departure from the normal.

11.—THE SENSE OF STABILITY AND BALANCE IN THE AIR

BY

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A. Introduction.

The faculty in man, which has raised him to a dominant position in the animal kingdom, is his capacity to make use of tools. He projects his powers of appreciation to the extremity of some mechanical contrivance, manœuvred by hand or foot, and so enormously extends his power to influence objects at a distance from his body. When we probe a wound or use a stick to explore the ground, we 'feel' at the end of the rod, not in our fingers. From such comparatively simple acts we can rise to the most complicated adjustments of eye and hand. For example, when shooting, our eyes are fixed on the bird passing across the field of vision; the gun is then thrown up with a movement so exactly regulated in time and direction, that the shot will arrive at a certain spot at the precise moment when the flight of the bird brings it to that position in space. We do not 'aim' or calculate some hypothetical distance 'in front'; nor do we actually see the gun at all. We carry out a reaction exactly adapted to the information given by our eyes. The more automatic this response the more likely is it to succeed in bringing down the bird.

Man not only uses this power of projecting himself to the end of some mechanical appliance in his work, but games were invented to exercise this faculty. Flying a machine heavier than air is nothing more than an extended application of this power, demanding adapted movements of every part of the body and limbs. No new elements come into the mechanical problems of flying that are not evident in riding a motor-bicycle, game shooting, cricket, or golf.

The vast majority of young men can acquire any of these aptitudes. A small minority are so constituted that they cannot do so; they 'do not feel safe' on a bicycle, and 'cannot hit the ball'. Such persons are rare amongst the healthy members of the community; but they form a small group who are 'not fond of games'. At the other end of the scale stand a small number of super-men, who seem to have been born with a natural gift, which rapidly carries them to a position above the average of their fellows.

Amongst candidates for the R.A.F. our aim must be to exclude those who are congenitally incapable of flying. At the same time we cannot hope to pick out super-men. We are concerned with the average youth who is capable of adjusting himself to conditions in the air. Any healthy young man, who is able to ride a motor-bicycle and play cricket or lawn tennis well, can be taught to fly.

Were this the whole problem it would not be difficult to select suitable candidates. But it must not be forgotten that the R.A.F. is a fighting force. A man must not only be a good

chauffeur, but he must be able to fight. I examined a pilot, who was acknowledged to be a remarkable aviator capable of flying any machine and apparently fearless in the air. But he was sent back from France because he could not fly over the lines. On the other hand, I have come across pilots with a fine fighting record, who were not good flyers in the technical sense, and neither knew nor cared anything about the details of their machine.

At first, candidates for the flying branches of the two services were admitted after a medical examination which varied greatly in strictness. But, with the coming of the Military Service Act, the rush of volunteers greatly increased. This enabled the authorities to raise the standard of the medical examination; but at the same time its aim was somewhat extended. An attempt was made, not only to exclude those who showed signs of pathological states, organic or functional, but to select men who would be able to fly well.

The various functions which come into play during aviation were analysed, and methods were devised to test the physiological activities on which they were supposed to depend.[1] At the same time the importance of the abnormal states induced by flying at high altitudes led to the invention of simple cardio-vascular and respiratory tests, which were found to be of value in appraising the general medical condition of a candidate or flying officer.

In its final form the medical examination of the Candidates Board was intended to fulfil a threefold object:

(1) To exclude all who suffered from pathological conditions. These included, not only gross defects of the heart, lungs and nervous system, but also such functional defects as 'nervous instability'.

(2) Some persons of normal constitution are liable to suffer in the air from certain grave disabilities, such as 'giddiness' and 'fainting'. These states are no more evidence of a pathological condition than is sea-sickness or inability to swing without discomfort. It was hoped that by applying tests which made a call on the activity of the semicircular canals, muscular sensibility and other fundamental sensory functions, it would be possible to exclude candidates who would suffer from these disabilities in the air.

(3) A certain proportion of pupils are rejected because they have difficulty in learning to fly; they are 'heavy on controls', 'make bad landings', or 'have no air feeling'. It was hoped that tests, founded on the sensations underlying balance, would exclude candidates who might show these defects.

On the protocol (Form C.B. 7) of the R.A.F. Commissions Board are three headings, 'Nervous Stability', 'Muscle Sense', and 'Vestibular Stability'; it is with these we are mainly concerned in the first part of this report.

[1] All the tests for balance were invented and carried out by Arthur H. Cheatle, F.R.C.S., who directed the Otological work of the Candidates Board.

In actual practice his opinion was based on the following methods of examination.

(1) The '*Nervous Stability*' of a candidate was judged from his past history, revealed by a few direct questions; by the evidence of nail-biting, ties or other signs of want of control, such as tremor of the hands and inability to balance a rod on a flat board with the eyes open.

(2) The condition of the '*Muscle Sense*' was estimated by the manner in which he balanced a rod on a flat board with his eyes closed and by his capacity to stand on one foot for 15 seconds under the same conditions.

(3) As tests of '*Vestibular Stability*' the candidate was asked to walk along a line heel to toe and to turn completely on one foot, so as to face in the opposite direction. The character of the entry under this heading was also determined by the manner in which he stood on one foot with his eyes closed.

Thus it is obvious that three mechanical tests were habitually relied on to give the information required. First, the candidate was made to extend his arms and hands to see if he was steady or tremulous. Then he was made to stand on one foot for 15 seconds and then on the other, both with the eyes open and shut; he was also made to walk along a line and turn at the word of command. Thirdly, he was made to balance a rod on a flat board by means of each hand in turn, with his eyes open and shut.

But, before any conclusion can be reached concerning the correlation of these tests with ability to fly, the results must be recorded in terms of the actual methods employed. No general opinion should be given such as 'Muscular Sense defective'; the actual facts of the examination must be recorded.

Unsteadiness, when standing on one foot with the eyes closed, was supposed to represent want of 'Muscle Sense'. I therefore examined a number of pilots and pupils, who were unable to carry out this test on either foot, for their power of recognizing passive movement at the various joints of the lower extremities. Now we know from other lines of research that this is the most delicate of all the measurable tests for what is usually called 'Muscle Sense' or 'Deep Sensibility'. So fine is the power of perceiving passive movement at all the joints from the great toe to the hip, that the normal individual can appreciate without difficulty a range of 1° or even less. This is scarcely perceptible to the eye and yet its direction can be accurately described by any intelligent person. Amongst the pilots and pupils who were unable to stand on one foot with the eyes closed, I did not find a single one who could not appreciate 1° of passive movement at all the joints of the lower extremity. It is obvious, therefore, that in the class of young men with whom we have to deal, inability to carry out this test has nothing to do with defective 'Muscle Sense', but is due to lack of motor control or want of resolution.

The condition of 'Muscle Sense' in the upper extremities is supposed to be revealed by the manner in which the rod is

balanced on a board, when the eyes are closed. I have carefully measured the power of recognizing passive movement in a series of pilots and pupils who were unable to carry out this test; records from the joints of fingers, wrist, elbow and shoulder, showed that they had no difficulty in appreciating a movement of 1°. Evidently, in the class of case from which our material is drawn, failure to carry out this test has nothing to do with defective 'Muscle Sense'.

'Vestibular Stability' is estimated by the power to walk along a line, to turn on one foot and to stand on one leg with the eyes closed. But there is no evidence to show that any of these acts bears a direct relation to the activity of the semicircular canals. Moreover, I have examined four pilots who were intensely giddy and vomited in the air, none of whom had the least difficulty in carrying out these tests perfectly.

B. The Tests and what they Reveal.

Although success or failure in these tests does not reveal the state of the 'Muscle Sense' or extent of 'Vestibular Stability', they form a valuable guide to the patient's physical and mental condition. I shall therefore consider these different methods of examination one by one, pointing out under what circumstances they are capable of yielding useful information. The material at my disposal consisted of 30 cadets, in 22 of whom I was able to obtain the after history; 20 pupils who were rejected for some inability to fly of a non-medical nature; 30 cases where a pilot or observer came to me on account of some disability such as vomiting or fainting in the air. In addition I have gained much useful experience from the patients under my care who passed through the annexe to the R.A.F. Central Hospital (Oakhill House).

(a) *Tremor.*

When a young man is made to hold his hands out in front o him, and at the same time to protrude his tongue, any considerable tremor is a sign of some definitely abnormal condition. A tremulous tongue may be indicative of chronic indigestion or of alcoholic excess; unsteadiness of the fingers, especially when they are abducted and brought together again, is a certain sign of lack of control. Tremor is not so much an indication of a neuropathic temperament as of a definite disturbance of function. It is not surprising therefore that Major Bowdler concluded that the group which contains 'tremor' showed a high correlation with want of aptitude to fly. He found that out of 54 candidates who were accepted in spite of 'marked tremor', 14 did not qualify, a ratio of success to failure of 2·8 to 1. Amongst 2,000 candidates who showed no abnormal signs 7·6 per cent. only were ultimately rejected.

The number of completely normal young men who show

tremor of the hands must be extremely small. In every case of a pupil, pilot, or observer that has come under my notice, this sign has been associated with some obvious cause. In a certain number it was due to alcoholic excess, and it was particularly evident in those pilots who took alcohol in order to be able to carry on their work. But, apart from alcohol, it is one of the commonest signs of stress of war service and was particularly frequent in those candidates who had already served in the infantry at the front. It was almost universally present in those officers who were admitted to hospital for some functional psychosis ('Shell Shock').

Tremor of the hands is a not infrequent sequel to malarial infection; it is more evident in delicate and precise movements, such as shaving, and the handwriting may be affected. Such unsteadiness comes out particularly well when attempting to balance the rod on a flat board.

Excessive smoking, especially the perpetual misuse of cigarettes, is responsible for much tremor of the hands in members of the R.A.F.

Thus, tremor is evidence of some disordered functional state, and should be looked for definitely in the course of the routine medical examination of candidates or pilots. It will be found most commonly amongst those who have been sent back from the front on account of stress of service, exhaustion, or states of anxiety.

(b) The Knee-jerk.

The condition of the knee-jerk is of little importance in the class from which the candidates for the R.A.F. are drawn. They are all young. None of them have reached the age at which syphilis is likely to have attacked the mechanism of this reflex, and 'exaggerated' knee-jerks are of little significance. Major Bowdler could find no evidence that any flying disability was associated with 'exaggerated reflexes'.

A condition not infrequently called 'exaggerated knee-jerks' is, however, an indication of loss of general control, but has in reality nothing to do with tendon reflexes. Sometimes on tapping the knee the whole body is thrown into agitation and the patient may even cry out. If the knee is carefully watched, the true knee-jerk is seen to precede the general commotion. This 'exaggerated knee-jerk' is in reality an uncontrolled reaction to a gentle blow and the same person will be found to start at a sudden noise. This 'general response' to tapping the knee is a valuable sign of loss of control, but is no indication of the condition of the deep reflexes. It is usually associated with a state of anxiety and is more likely to be found in unfit pilots than in candidates for the R.A.F.

(c) Walking a line heel to toe and turning on one foot.

The result of this test is recorded by the Examining Board under the heading of 'Vestibular Stability'. But there is nothing

to show that inability to walk a line and to turn on one foot is evidence of anything more than clumsiness in action or slowness of comprehension.

We examined a number of cadets, all of whom had been passed by the Candidates Board and had already begun to fly. We were able to obtain the ultimate history in 22 cases: 13 flew well and amongst them 9 could walk a line and turn on one foot well, but 4 carried out this test badly. Amongst the 9 pupils who failed to qualify, 3 walked and turned well, whilst 6 were bad at this test.

Such numbers are useless for any statistical comparison: but certain points came out on closer personal examination of those who failed. One pupil showed astonishing lack of comprehension of the task he was asked to perform; when told to turn on one foot only, he walked round in a circle and repeatedly turned in this way, although we demonstrated to him the manner in which we wished him to carry out the test. This man did 6 hours and 25 minutes dual flying; but when the time came to go up alone, he 'went sick' and did not fly again.

The same failure to comprehend what was required was apparent to a less degree in two other cases amongst the pupils who were finally rejected. It has nothing to do with want of stability, but is evidence of a slow response to unexpected verbal commands.

Another cadet, who had fought successfully in France, found considerable difficulty in walking heel to toe and turning on one foot. He ultimately became an excellent scout pilot, but confessed that he disliked dancing. In fact it seems to us that this test is more likely to show ability to dance than any capacity to fly.

But whatever relation it may bear to flying it is certainly not evidence of 'Vestibular Stability'. For, out of 8 pilots who suffered from profound giddiness associated with vomiting in the air, two only failed to pass this test; both of these men were tremulous and showed other neuropathic signs and symptoms.

(d) Standing on one foot for 15 seconds with the eyes closed.

If a candidate is unable to carry out this test, his failure has been attributed to defective 'Muscle Sense'. But I carefully tested the power of recognizing passive movements at the various joints of the lower extremities in several R.A.F. pilots and pupils, who failed to stand on one foot with the eyes closed. I selected the grossest cases only; but in no single instance was the power of recognizing posture and passive movement affected. Moreover, these same persons, who were unable to stand on one foot, could do so with both feet on the ground even when the eyes were closed; Romberg's sign was completely absent, showing that the impulses passing up the posterior columns of the spinal cord were not affected. There is no evidence, therefore, that inability to stand on one foot for 15 seconds with the eyes closed

bears any relation to disturbed sensations from the muscles and joints, in the class of young men with whom we have to deal. Moreover, all the pilots and pupils who failed to carry out this test in spite of repeated attempts, showed considerable tremor of the hands and were evidently suffering from some neuropathic or psychopathic condition.

Amongst the cadets who ultimately proved to be successful pilots, two carried out this test poorly. Both showed some tremor of the hands, and one of them had come home after fighting in France to join the R.A.F. Of the nine successful cadets, three showed defective power of standing on one foot, and of these two had distinct tremor of the hands.

Amongst 20 healthy pilots who were rejected on account of inability to fly and not for any physical reason, 15 carried out this test perfectly. Of the five who could not stand on one foot for 15 seconds on the first attempt, three were able to do so on a second trial and two only failed three times on each foot.

But amongst 20 pilots who came under my care for some pathological condition, such as vomiting or fainting in the air, fatigue, or anxiety, 11 showed gross defects in carrying out this test. Thus if we place together in one group the unselected cadets and the officers who had been rejected for defective flying capacity, we obtain 42 healthy individuals: amongst them were 10 cases where this test could not be carried out perfectly. On the other hand, of 24 pilots and pupils who ceased to fly because of some morbid condition in the air, 15 showed considerable difficulty in balancing themselves on one foot.

Thus it is evident that amongst candidates, pupils, and pilots of the R.A.F., inability to stand on one foot with the eyes closed for 15 seconds is evidence of some want of control and is not due to defective 'Muscle Sense'.

Secondly, this test is more likely to be badly executed by those who show other signs and symptoms of fatigue or anxiety, whether temperamental or acquired. It is not directly a test for flying capacity; but a man who has difficulty in carrying it out successfully will probably be found to be suffering from mental or physical stress. This will ultimately affect his handling of machines heavier than air, although it may have no influence on his work as an airship pilot.

To stand on one foot with the eyes closed for 15 seconds requires not only perfect automatic control but some determination. One of the respiratory tests invented by Colonel Flack also calls for a certain amount of resolute effort, and it is interesting to notice the frequency with which the results of the two methods fall together. The pilot under examination is told to blow into a U-tube and to support a column of mercury 40 mm. in height for as long as possible. Forty seconds is taken to be normal, although a healthy young man usually greatly exceeds this period. But the result is gauged not only by the time but also by the effect on the patient: if he becomes suffused and distressed he is considered to have failed even if he slightly exceeds 40 seconds.

Amongst 20 pilots who suffered from some abnormal condition in the air, 9 failed to pass both the balancing and U-tube tests. One showed defective power of standing on one foot, but supported the mercury for 45 seconds; one other failed in the respiratory test, but succeeded in balancing himself on one foot.

This association between the results of the two methods of examination might have been anticipated. Both depend on sustained effort, and anything which diminishes the power of concentration will influence both tests. All the 9 pilots who failed were suffering from fatigue, anxiety, want of sleep, bad dreams, or other analogous symptoms; it is such states which above all others are associated with defective concentration and diminished control.

(c) Balancing a rod on a flat board with the eyes open or closed.

This is an easy test to carry out and requires no apparatus that cannot be improvised out of the lid of a cigar-box and a small tuning-fork with a flat base. The board is placed on the table with the rod standing upright on that part further from the person to be examined. He is then asked to grasp the edge nearest to him with his fingers, to raise the board to the level of his shoulders and to replace it on the table without upsetting the rod. Should he fail at the first attempt with either hand, he is allowed to try three times in succession. He is then examined in the same way with the eyes closed.

Failure to balance the rod with the eyes open was assumed by the Examining Board to be evidence of want of 'Nervous Stability', a heading shared with Tremor, Tics, and other symptoms of want of control. But inability to pass this test with the eyes closed was classed as due to defective 'Muscle Sense'.

I therefore selected for closer investigation several of the worst cases, where the subject of examination failed entirely to balance the rod with either hand, when his eyes were closed. In no instance could I find any measurable defect in 'Muscle Sense': 1° of passive movement could be accurately appreciated at all the joints of the upper extremity. It is evident, therefore, that, amongst pilots and candidates of the R.A.F., failure to balance the rod with the eyes closed is not dependent on lack of Muscular Sensibility. It is, in fact, simply another and more severe method of examining the same want of control and clumsiness of action, betrayed by balancing the rod with the eyes open.

Most normal persons find greater difficulty in balancing a rod on a flat board with the eyes closed than when they are open. Now, whenever some function of the nervous system is defective, the more complex and difficult task shows evidence of failure before one that is simpler and easier of execution. It is not surprising, therefore, to find that out of 20 cadets who had already begun flying, 4 showed some difficulty in balancing the rod with the eyes open and 8 with the eyes closed; but this

difficulty bore no relation to their subsequent career as aviators. Moreover, amongst 20 pupils rejected solely because of inability to fly, 5 had some difficulty in balancing the rod with the eyes open, 10 with the eyes closed. Thus if we compare the normal cadets and rejected pupils there is nothing to show that there was any material difference in behaviour between those who could and those who could not fly, provided they were physically healthy.

But when we turn to the 25 pilots or pupils who suffered from abnormal symptoms in the air, the proportion of failures was nearly double as great; 13 had difficulty in balancing the rod with the eyes open, 19 with the eyes closed. Evidently this test reveals some condition common amongst those who have suffered from pathological states in the air. But provided the individual is otherwise healthy, it does not bear any direct relation to flying capacity.

On looking through the records of those who failed more or less grossly in this test, the high proportion of cases of tremor is at once evident. This might have been anticipated; for any tremor makes it difficult to carry out an operation which requires a steady hand. Out of 28 pilots who had suffered from pathological states in the air, 14 were tremulous and all but one showed difficulty in balancing the rod on the board. In the same way, out of 50 cadets and rejected pupils 11 showed some tremor of the hands, and all of these failed to balance the rod satisfactorily.

But it must not be supposed that this test is only another means of discovering tremor. Amongst 28 pathological cases there were 7 persons who were not tremulous but could not balance the rod with normal certainty. In the same way, amongst 30 cadets and 20 rejected pupils, 9 could not carry out this test satisfactorily, though free from tremor. In almost every instance of this class I made a special note that the failure was due to erratic conduct, carelessness, want of resolution, or defective comprehension of the task and the best method of carrying it out. In other cases the movements were 'clumsy' and 'stiff', or the subject seemed 'utterly worn out' and 'tired'.

Thus we may conclude that, provided the subject of examination is in perfect physical health, this test has no direct bearing on his capacity to fly a machine heavier than air. But, on the other hand, it is a useful method of detecting states of exhaustion, flying-stress, insomnia, and other neuropathic and psychopathic conditions, in an early stage of development. There is no difference in principle between the test carried out with the eyes open or shut. The latter is a more difficult task, and therefore tends in most cases to show defects sooner than when the balance is guided by sight.

(*f*) *Conclusions.*

Some of the methods of examination discussed in this chapter are of sufficient value to form part of the routine medical

examination of candidates and pilots of the R.A.F. Tremor of the hands and tongue must always be carefully noted. The candidate should be asked to stand first on one leg and then on the other for 15 seconds with the eyes closed. He is also made to balance a rod or tuning-fork on a flat board with either hand in turn, first with the eyes open and then with them closed. He is allowed three attempts, and the character of his failure to carry out this test should be recorded, if possible.

In every case the actual method of examination must be recorded, and all such general categories as 'Muscle Sense', 'Vestibular Stability', and the like, must be avoided.

With such material as we meet with in the R.A.F., consisting as it does of young men in whom gross organic disease is almost absent, these tests reveal the condition of physiological or psychical control. Such control may be defective from innumerable causes; some of the most potent are fatigue, physical or mental stress, anxiety and fear. All of these conditions may appear in the course of the work of any aviator, but were enormously aggravated by flying under war conditions.

C. 'Giddiness', Vomiting, and 'Fainting' in the Air.

(*a*) *Introduction.*

A pilot may lose control and become unconscious in the air from many various causes. Of these want of oxygen at high altitudes is perhaps the best known, and has formed the subject of several previous Reports. It is not my intention to deal with this condition, but to consider abnormal symptoms which may occur at any height and are not due to physical or chemical deficiencies in the atmosphere.

These are usually called by the sufferer 'giddiness', 'dizziness', and 'fainting in the air'. Unfortunately many medical men record them as 'vertigo' and 'syncope', without any qualification or explanatory statement of what actually happened. Nothing could be more fatal for the progress of knowledge than this widespread tendency to translate popular nomenclature into nosological language. To say that an aviator suffered from 'vertigo' inevitably suggests that the cause of his trouble was the semicircular canals, whilst 'syncope' attracts attention to the cardio-vascular system.

Throughout this chapter I shall allude repeatedly to the way in which the patient reacts when rotated in a chair. American workers have laid great stress on this response to rotation, and have carried out their observations in such a way that each group of semicircular canals is stimulated in turn. In fact, this method of examination formed, at one time, the determining test for admission to their Flying Service. A candidate was

obliged to react in a certain manner or he was not accepted. The Report of the American Surgeons states—

'It was decided to reject applicants whose vestibular apparatus gave evidence of motion-sensing acuity below a certain degree, albeit it was fully recognized in establishing this limit, that it in no way represented a line of demarkation between acuities of this perception compatible with and incompatible with flying.'

The extent of the response of the vestibular apparatus to disturbances of equilibrium was estimated in two ways. First, the candidate was rotated with his head in a strictly regulated position and the duration of the nystagmus was measured. Secondly, without rising from the chair and with his eyes still closed, he attempted to find the observer's finger, which was placed in a certain, previously familiar, position. If the deviation to this test did not reach a certain amount the candidate was assumed to be endowed with less than the normal vestibular acuity; if, on the other hand, it exceeded certain limits, arbitrarily fixed, he was rejected as over-sensitive. But this method of examination is purely empirical, and the data obtained have not so far been correlated with ability to fly.

I have not attempted to check these results; for throughout this work I have used the rotating chair, not as a method of measuring the response of the semicircular canals, but as a means of inducing an abnormal reaction. A healthy man responds in a certain way to rotation, although the degree of giddiness varies greatly. But in certain persons, who suffer from morbid phenomena in the air, the reaction is abnormal and excessive. It is frequently possible, by rotation, to induce physiological states and sensations analogous to those experienced in the air: the disability can be reproduced in a minor form. This is true, not only in cases of 'giddiness', but also in those where the pilot has 'fainted' in the air.

When we sit upright in a chair, the horizontal canals are not strictly in a plane parallel to the ground; they are slightly tilted and the head must be inclined to about 30° before they become strictly horizontal. But this is not the natural position; the head is usually carried so that the eyes look directly forwards and not on to the ground. This is the posture to which we are adapted in daily life, and the head can be turned rapidly to the right or left without giddiness or abnormal symptoms: for these movements occur more frequently than any others under natural conditions. And yet at no time, either during this static pose or on lateral deviation, are any of the semicircular canals in a position suitable for exclusive physiological stimulation. If we want to test the response of the horizontal canals specifically, the head must be suitably adjusted before rotation: but if, as is my intention, we wish to study the general functional reaction of the patient, he must be placed in the natural position seated upright in the chair.

It is important to understand the different aims of the two methods of carrying out this test. Those who carefully place the head in such a posture, that each set of canals is stimulated in

turn, look to the specific nature of the physiological response. On the other hand, I was anxious to determine, not the afferent results of such stimuli, but the way in which the patient could adapt himself to somewhat violent sensory impressions. My object was to examine his control in face of disturbances of equilibrium. Similarly, I not infrequently tested his reaction to a slight blow on the knee or to a sudden noise.

When a healthy man is rotated ten times in twenty seconds with his eyes closed, the results depend mainly on the position of the head. I have not attempted to modify its posture so as to stimulate any one set of semicircular canals alone; but the patient was directed to sit upright in the chair, as if he was gazing directly forwards. On opening his eyes the room seems to be going round in a direction opposed to that in which he was rotated. A normal man is not giddy, and suffers from no nausea, headache, or other discomfort.

If he is asked to rise and walk forwards he may tend to deviate, but rapidly recovers himself and reaches the table, five paces in front of him, without difficulty. When the chin has been held somewhat downwards, so as to bring the one set of canals strictly into the horizontal position, this deviation tends to take place in the direction of the rotation. But with the head in the erect position this is not the case in most instances; thus rotation clockwise is usually followed by more or less deviation to the left.

It is most important to record all rotation, actual or apparent, in terms of the long axis of the body and not as movements to the right or left. But deviation on rising from the chair is described as 'to the right' or 'to the left', because this is the only movement that can be actually observed, although the patient is often aware that it is the expression of a rotatory sensation.

In all my cases the patient was first turned 10 times in 20 seconds clockwise. Then, after a pause, varying in length according to the severity of the reaction, he was rotated in the opposite direction. Usually this second stimulation produced a somewhat greater effect than the first, particularly in subjects who showed other evidence of some abnormal condition.

(*b*) *Giddiness associated with temporary abnormalities of the Auditory Apparatus.*

In order that we may be able to adapt ourselves to changes in position the auditory apparatus must be structurally sound. This is assured in most cases by the careful examination of candidates before they are accepted into the R.A.F.

But Sydney Scott[1] has pointed out that giddiness and other allied symptoms may occur in aviators who are unable to obtain a free and immediate passage of air through the Eustachian

[1] *Journ. of Laryngology, Rhinology, and Otology*, Feb. 1919, Vol. XXXIV, No. 2, p. 51. A fuller account of these researches is also published as a Report of the Air Medical Investigation Committee (Special Series, No. 37).

tubes. The ears may be normal, but the pilot suffers from a cold in the head. The air no longer passes freely through one or both Eustachian tubes and, when he rises to a considerable height or descends with great rapidity, an abnormal condition of tension is produced in one or both middle ears. This, acting on the vestibular apparatus, evokes intense giddiness and is accompanied by pain of more or less severity. Not infrequently effusion, or even haemorrhage, occurs into the middle ear.

Most experienced pilots are conscious of the salutary effect of swallowing during a rapid descent, and habitually chew gum for this purpose. But, in some cases, a temporary condition of the nose or throat may make it impossible to regulate the tension within the middle ear, with disastrous results to the pilot.

In the following instance the giddiness occurred whenever the patient caught a cold in the head, although his auditory apparatus was otherwise normal.

Case No. 1. 2nd Lieut., aged 19.

He first went into the air in September 1917 and had flown for 13 hours solo on Avros before he felt any discomfort. In December 1917 he caught cold, when sleeping in a canvas hangar with snow upon the ground. He went up one morning, with a cold in the head, and suddenly 'felt dizzy': his head seemed 'to be whizzing round inside', and he 'felt strange'. He went up frequently during the next few days and was 'giddy' on several occasions. He did not vomit and was not nauseated. Throughout this period he was deaf.

He went away on leave, and recovered entirely. On returning to his squadron, he flew solo for 9 hours in perfect comfort, and graduated on April 9, 1918.

He was then transferred to another squadron to fly service machines. Here he caught another cold, and one day, when in the air, whilst suffering from headache and running at the nose, he felt himself becoming giddy at 3,000 feet. He shut off his engine, but does not know how he came down. He was flying an Avro and, according to the report of his Wing Commander, started to spin. He stalled the machine at about 30 feet, and broke some struts in landing, but was not hurt.

He was seen by me in September 1918, four months after the last occasion on which he had been in the air.

He was then a well-built young man with somewhat narrow nostrils. He had been operated on successfully for adenoids at the age of 11 years, and there was no obvious abnormality in his throat or nose. His hearing was good, and the membranes were normal and not retracted: but he said that, whenever he caught a cold, something went wrong with his ears.

Respiratory and cardiac tests showed no gross abnormality, but his balance on one foot was bad. He failed three times in succession to stand on the right foot for 15 seconds, and succeeded with difficulty in doing so on the left. He balanced the rod on the flat board at the first attempt with the right hand, when his eyes were open, and on the second attempt with the left hand. But with the eyes closed, he failed altogether to carry out this test with the left hand, and only succeeded on the second attempt with the right. And yet, on testing his power of appreciating passive movement, he could recognize 1° at all joints of both upper and lower extremities.

When he was rotated, he did not deviate definitely in either direction, and touched the spot on the table perfectly. But he complained that, as soon as he rose from the chair, he felt as if he was 'moving backwards and

forwards'. He seemed to move 'first from right to left, and then back again from left to right'. The window in front of him 'seemed to be doing the same, wavering backwards and forwards'. He was not giddy, and felt perfectly normal, as soon as the 'wavering' passed off. There was no nausea or headache.

From this case there is an easy transition to such a one as the following, where the throat was in an obviously abnormal condition.

Case No. 2. Lieut., aged 27.

He joined the R.F.C. in June 1917, and went to France on January 31, 1918, flying S.E. 5. He began to notice that, when coming in after high scouting, he was a little deaf in the left ear. When he descended from a height, he had to 'blow up his ears', and 'sometimes they would stay plugged for three or four days'.

On April 3, 1918, whilst coming home to the aerodrome, he got into a backwash and went 'dizzy'. He spun from 4,000 feet to 2,500 feet, but did not lose consciousness. He knew what was happening, pulled his machine out of the spin and followed the others home. On alighting from his machine, the giddiness continued for some time.

I saw him nine days later and his tonsils were red and swollen, the left more so than the right. The membranes were normal, and he was not then deaf.

Both these cases are examples of the ill-effects produced by uncorrected changes of tension within the auditory apparatus. Sydney Scott has shown, from careful examination of a large number of pilots at the front, that such abnormal conditions in the middle ear are amongst the commoner causes of giddiness in the air. A healthy man is suddenly exposed to unnatural stimulation of the essential sensory mechanism due to uncorrected tension in the auditory apparatus: he responds in a normal manner with a more or less acute vertigo. Here it is not the reaction of the individual or the response of his semicircular canals that are in fault, but the abnormal and unequal tension in the middle ear.

But 'giddiness' may occur in aviators apart altogether from such external stimuli. In such cases their abnormal state in the air must be due to one or two causes. Either the sensory impressions evoked by changes of bodily posture must be excessive, or the general resistance to the uncontrolled acceptance of such impulses must be profoundly diminished. This defective power of integration and control may be acquired or constitutional. Such cases are of profound diagnostic and scientific importance, and form the subject of the next two sections of this chapter.

(c) *Giddiness in the Air with no abnormal conditions in the Auditory Apparatus.*

Most healthy persons can be made giddy, provided the rotatory movement is sufficiently violent, and especially if the head is held in some abnormal position. This reaction is not a patho-

logical condition; it is a normal response to an acute disturbance of equilibrium. But the ease with which it can be evoked varies greatly: some, in childhood, were not able to swing without discomfort and were sick on a train journey. As they grew up, however, this response was evoked less easily, and, provided the stimulus was not unusually severe, they differed little from their fellows.

In the same way many normal men become giddy when first exposed to rapid changes of posture in the air. After a few turns the instructor carries out some aerobatic evolution and, when first looped, rolled, or spun, many pupils become uncomfortable and a certain number vomit. But the majority rapidly recover and may become expert and bold aviators. They have adapted themselves to the new conditions: the stimuli from the peripheral end-organs no longer dominate the field of response. They are controlled or suppressed, not by the will, but by that power of adaptation which is one of the most potent factors in the activity of the central nervous system. In the course of evolution the lower centres have come increasingly under the dominance of those of higher functions and more recent development. Actions, which in lower animals can be carried out by the spinal cord alone, become impossible in man without the co-operation of the centres in the mid-brain.

Even in the fully developed nervous system of man the acquisition of some new aptitude is associated with an increasing control of higher centres. We learn to adapt ourselves to the conditions around us and cease to be the victims of unco-ordinated sensory impressions.

In order that any of these acquired aptitudes may be carried out in a perfect manner attention must be concentrated on the end and object of the movement, and the motor act must become as nearly as possible automatic. A man shoots his best when his eye is fixed on the bird and he is not conscious of his gun. In the same way an aviator must be able to concentrate on the evolution he wishes to perform and carry out the necessary acts automatically. To turn a corner on a bicycle or to bank an aeroplane 'you just lean over' and the desired change occurs without further thought. The man who flies by verbal rules is a bad pilot and will certainly come to grief.

Anything which diminishes the power of concentration tends to lessen control over the reaction of the lower centres to sensory stimulation. An attack of influenza, a 'crash', domestic worry or fear, all act in the same direction. A pilot who was giddy when he first went into the air, but recovered completely, may fall back to his original mode of reaction and be unable to carry out any aerobatic evolution. Such persons are no longer normal, not because the response is a pathological one, but because, for a time at any rate, they have been reduced to a lower level of functional efficiency.

My first example is that of a perfectly healthy man, who never recovered from the tendency to become giddy and to vomit in the air. The case is an instructive one, because he succeeded in concealing his disability and was only saved from death in France

by the prompt assistance of two colleagues. Moreover, since he was marked unfit for flying, he has repeatedly been in the air as a passenger during the course of his work, and appreciates exactly the conditions which render him uncomfortable.

Case No. 3. Capt., aged 23.

After serving in the Infantry he was transferred to the R.F.C. and began to fly on June 15, 1917. He graduated in October and went to France as a Scout pilot on November 14, 1917, flying Sopwith Camels. He did 150 hours in the air, of which 50 were in France.

The first time he was taken into the air on an Avro he vomited at about 2,000 feet. So long as he flew straight he managed without difficulty, but when he turned rapidly or 'threw the machine about' he was attacked with nausea and occasionally vomited. By coming down whenever he was uncomfortable, and by doing as little 'stunting' as possible, he managed to conceal his disability and was sent out to France after 80 hours in the air.

Here he felt no discomfort at first, because his duties consisted mainly of patrolling at about 10,000 feet. One day, however, he was attacked by the enemy and compelled to turn rapidly in the air: this caused him to vomit severely. He was so ill that he could not look about him, and the enemy were on his tail, firing into his machine before he realized what had happened. Two of his companions saved him and drove off the Germans. On coming down safely he was obliged to go to bed for two or three hours. He went up three times after this adventure, but vomited on each occasion and was sent home.

As a child he disliked swinging, and was easily made sea-sick. At the age of 14 he was swung upon a gate and was so sick that he was obliged to go to bed.

I saw him on his return from France. He was well built, strong, and healthy. He seemed so completely normal that I took him to the Candidates Board, and the examiners kindly put him through all the tests for me without asking any preliminary questions. He passed without qualification.

When, however, he was rotated in the chair the general reaction was excessive, although the visible response was normal in character. After ten turns clockwise, he rose and deviated to the right; the room seemed to be moving in a direction opposed to that in which he had been turned. After a pause of ten minutes, he was rotated counter-clockwise; he then staggered to the right and to the left unsteadily, whilst the room seemed to go round with the hands of the clock. This response was not abnormal, but the general reaction was disproportionately great. He was attacked with profound nausea, his face and hands sweated, and he said he felt exactly as he does in the air.

He was a highly-trained scientific student and was therefore given employment in the Technical Department. In the course of his work he frequently goes into the air as a passenger, and suffers from no discomfort so long as the flight is steady. But on one occasion recently he was up in a D.H. 9 with a B.H.P. engine, which gives off unpleasant fumes near the observer's face; the air was 'bumpy', and the combination of the two conditions caused him to vomit.

This is an example of a perfectly normal man, who has never been able to adapt himself to disturbances of equilibrium. The actual response to rotatory stimuli was normal in character, but the reaction it evoked was excessive.

The next case is one where the profound reaction to change of posture was one aspect only of a congenital want of nervous control, in a man of unusual physical strength and athletic ability.

Case No. 4. 2nd Lieut., aged 23½.

He served for three years in the Infantry, and gained his commission from the ranks. He was splendidly built and had been a professional football player; but he had always noticed that if he looked up as he ran, he became giddy and tended to fall.

It is interesting to notice that, in spite of his build, appearance, and fighting record, he had always been 'nervous'. As a child he could not sleep without a light and was terrified of the dark. He always dreamt unpleasantly, and on waking 'saw big ugly faces' in the room. This occurred frequently up to the age of 16. During the last twelve months his unpleasant dreams had recurred; they mostly took the form that he was with the Infantry, and that 'they were in a tight place'.

After joining the R.A.F. he noticed that he did not suffer in the air so long as he flew straight, but turning made him giddy. He was most uncomfortable when the nose of the machine was put down, but banking always upset him. After several trials he was finally rejected as permanently unfit for pilot or observer.

This man's behaviour to the usual tests was in striking contrast to those of No. 3. He could not support himself for 15 seconds on either foot with the eyes closed. He failed altogether to balance the rod on the flat board, either with the eyes open or closed. But he showed equally gross defects to the respiratory tests, and could not support 40 mm. of mercury for more than 30 seconds; his pulse-rate behaved in a normal manner throughout, showing that this failure was not due to any cardio-vascular inadequacy.

From previous experience of such cases, I suspected that he might react violently to rotation, and I therefore turned him five times only in each direction; an interval of five minutes elapsed between the two observations. On being rotated he became so giddy that he sat coiled up clinging to the arms of the chair, unable to move. He did not even attempt to rise, but said he felt extremely ill, exactly as when he was in the air.

This is an example of an excessive reaction to sensory stimulation, due to lack of central control. In spite of his unusual physical development, this man was endowed with a psychopathic temperament, and the response to unusual stimulation of the vestibular apparatus was manifested in the form of a minor anxiety neurosis.

The next case shows that a pupil who starts with giddiness and vomiting in the air may overcame his disability and develop into an able pilot. But anything which diminishes general control may cause him to regress to his original condition.

Case No. 5. Lieut., aged 22.

After 3 years and 11 months in the Infantry he joined the R.F.C. During his first dual flight on an Avro he felt sick and vomited. He recovered entirely, quickly gained his wings, and went to France to fly Sopwith Camels. He had no giddiness, nausea, or other discomfort, even when 'stunting'.

But, after 90 hours war flying, he was shot down in aerial combat and chased from 9,000 feet by his opponent. On reaching the ground he found himself unhurt, but pinned under his machine, which had turned over.

Six days later he resumed flying and discovered that he had lost all confidence. He flew for 20 hours, but could not face the fighting and was sent home. After two months' rest he seemed to have recovered entirely, and was posted as instructor to a Training Squadron at home. He went up three times with the Wing Instructor and on each occasion vomited violently.

As a child he disliked swinging, and felt 'dizzy' and 'sick'. On a railway journey he cannot sit with his back to the engine without feeling 'squeamish'. All the members of his family react in the same way, both to swinging and to travelling by train.

The only one of the general tests which he carried out badly was balancing the rod with the eyes closed; he succeeded on the third attempt only with the right hand, and with the left failed altogether. He showed no excessive reaction to rotation; when turned ten times clockwise or counter-clockwise he deviated in the opposite direction, exactly like a normal person, but recovered himself quickly. The room seemed to be moving horizontally opposed to the direction of rotation. He did not suffer from nausea or any discomfort.

This was an instance when, in spite of an hereditary tendency to giddiness and nausea, the pilot adapted himself to the new conditions perfectly. But, with the shock of being shot down, he regressed, and all his old disability returned in spite of the fact that he was physically in perfect health.

In the following example the patient had a natural tendency to vomit in the air, but gained sufficient control to fly as an observer for more than three months in France and to take part in much aerial fighting. He suddenly regressed in consequence of acute fear.

Case No. 6. 2nd Lieut., aged 19.

He began his training in the air as an observer in April 1918 on a D.H. 4, and vomited three times in six flights. The nausea started about ten minutes after he left the ground with 'a drawing in the stomach up to the throat'; and as soon as he experienced this sensation he knew he must vomit. When it was over he felt better, and could go on flying comfortably.

The nausea came on apart from any aerobatic evolution; but when rolled, looped, or spun, he was 'dizzy' and 'sick' all the time.

He went to France as an observer and flew for 3½ months in a Bristol Fighter, under war conditions. So long as he was not heavily 'stunted', he enjoyed his work and did not vomit. But, of all evolutions, rolling upset him most.

At the end of August 1918 he suddenly went to pieces under the following circumstances. His squadron was going to take part in a combined attack during the afternoon. In the course of the morning a new pilot went up for a turn in the air and dived into the earth on the aerodrome, killing himself and his observer. Shortly afterwards a second pilot and observer were killed in the sight of the patient and his companions. But the pre-arranged military operation could not be postponed, and he was obliged to go up with his squadron the same afternoon. He was intensely frightened and vomited in the air. From that time onwards he was sick whenever he went up, even when flying straight; finally he was so ill that his pilot brought him back shortly after starting.

He could never swing as a child, because it made him giddy, and he always vomited in a train, and sometimes even in a tramway car. When

uncomfortable in the air his sensations were exactly those he experienced in childhood before he was sick in the train. He had often suffered from sea-sickness.

Physically he was in perfect health, and was not tremulous. He passed all the usual balancing tests, and had no difficulty in supporting 40 mm. of mercury by blowing for 40 seconds. The pulse did not react abnormally to this form of effort.

But when rotated in the chair his reaction was characteristic. Turned ten times clockwise, he rose, stood with his feet apart, leaning forwards, shaking. He did not deviate, but moved slowly and unsteadily directly forwards to the table. He said that the room was not going round, but that his 'feet seemed to be rocking'. 'I had the drawing feeling in my stomach up to my throat, that I know so well in the air.' After a pause of ten minutes he was rotated in the opposite direction with exactly the same result. He stood unsteadily, in the same attitude, with his feet apart, quaking as if in fear.

Here, a healthy young man, relatively over-susceptible to disturbances of equilibrium, succeeded in adapting himself sufficiently to carry out his work as an observer under war conditions. But, with the development of an anxiety neurosis, due to an acute state of fear, the physical reaction became severe and overwhelming.

In the following case the patient had never experienced any discomfort until he attempted to fly after an attack of influenza. He then became giddy and vomited repeatedly in the air.

Case No. 7. 2nd Lieut., aged 19½.

He thoroughly enjoyed flying from the first, and had never had an accident. He obtained his wings without difficulty and was preparing to go to France, when on June 30, 1918, he had an attack of influenza. He was in bed for ten days with no complications and then went on leave.

On July 27 he went up for the first time since his illness as a passenger and vomited at 1,500 feet. 'I was giddy; my eyesight seemed blearv and full of specks, and it was like a bad bilious attack.' He was so determined to conquer this feeling that he went up again the same day and again vomited. This was a simple straight flight in an Avro.

As a child he thoroughly enjoyed swinging, and he has never been sea-sick, even when fishing from a small boat.

I saw him at the beginning of September 1918 and he was then easily tired, even by a short walk. He had lost a good deal of weight since the attack of influenza, but there were no abnormal physical signs in the lungs or heart. The balance of his hands was poor, and he was unsteady when standing on one foot. He had considerable difficulty in raising the rod on the flat board, especially with the eyes closed. But the respiratory tests were fairly well carried out [U-tube 45 secs.], and the pulse did not react abnormally to effort.

When turned ten times clockwise, he rose, deviated slightly to the left, but touched the spot on the table without difficulty. The room seemed to be revolving in the direction opposite to the rotation. He said he felt giddy, and looked it. The reaction, when turned ten times counter-clockwise, was exactly analogous; he deviated to the right and the room seemed to be going in the same direction.

In neither case was the visible response abnormal, but its effect upon his general condition was excessive. Throughout the rest of the day he felt

sick; his appetite was not impaired, but he had a continuous feeling of nausea. He also complained of an abnormal sensation, as 'if something was pressing down in the back of my head'.

This seems to be a case where the response to rotation was not abnormal; but owing to the diminution of general resistance, due to influenza, normal sensory impulses evoked an unusual general reaction.

The next case illustrates how a flying officer, who had never known discomfort in the air, may become giddy and vomit as a sequel to a gastro-intestinal disturbance. It also shows the close relation between the two conditions 'vomiting' and 'fainting' in the air.

Case No. 8. 2nd Lieut., aged 29.

He began to fly in Canada in January 1918 and enjoyed it extremely. In June he was posted to a squadron in England, and whilst there, during the first week of August, suffered from a short attack of diarrhoea. Throughout the four days of its duration he continued to fly, but felt so weak that he was forced to use two hands to the controls on steep turns; suddenly, at about 1,000 feet, he was attacked with 'dizziness' and thought he was about to vomit. After resting for a few days, he seemed to have recovered entirely and took two short flights without ill effects.

He was then posted to another squadron and began to suffer from indigestion, with 'wind', 'cramps in the stomach', and 'some pain shortly after taking food'. He was given a laxative, and this started another attack of diarrhoea. He did not fly for a week, but on September 8, 1918, after 20 minutes in the air, he became 'dizzy'. His head seemed to 'swim', his vision became hazy, and at about 100 feet everything 'went black' for a few seconds.

After a good night's sleep he went up again next day and was perfectly comfortable, so long as he flew straight; but as soon as he began to circle round a ground target he became 'dizzy'. 'The target started going round with me.' He felt sick, broke out into a sweat, and repeatedly put his head over the side, partly because he was certain he was about to vomit, and partly in the attempt to obtain fresh air. He kept on swallowing and felt all would be right if thereby he could prevent something coming up from his stomach.

He has never been sea-sick, and could swing with pleasure as a child.

I saw him in October 1918. He was still suffering from flatulent dyspepsia; his bowels were opened once or twice daily, and the motions were always somewhat loose. The tongue was clean, the teeth were fairly good, and there was very slight gingivitis. There were no abnormal physical signs in the heart or lungs, but he had distinctly lost weight. He slept well, and did not dream unpleasantly.

He passed all the tests for balance without difficulty, but rotation in the chair produced a characteristic reaction. On turning him ten times clockwise, he rose, swayed with eyes half closed, and appeared dazed; but he stepped forwards and touched the table without deviating definitely in any one direction. He said: 'Things seem to start going to the right and yet I seemed to be able to control it by blinking. Everything went misty just as it does in the air, and my stomach felt funny.' On rotation in the opposite direction, he rose slowly and staggered to the right, pulled himself together and moved to the left, finally touching correctly. He said: 'This time it was more as if I could not get where I wanted and misjudged my

distance. I thought I was right on the point, when I was a long way off. This is just like my landings after an attack in the air.' He added that he felt 'squalmy' in the stomach.

In this case the abnormal reaction took at one time the form of giddiness and nausea, and at another time that of partial unconsciousness; it forms a transition to the next group, where the pilot is said to 'faint in the air' at low altitudes.

(*d*) '*Fainting*' *in the Air.*

In the previous section I have described a series of cases where the reaction to disturbances of equilibrium took the form of giddiness and nausea. Another not uncommon abnormality is what is usually called 'fainting' in the air. A 'mist' or 'haze' comes before the eyes and 'all goes dark'. It is not an unpleasant sensation, and is said to resemble closely the early stage of an anaesthetic. This passes into complete insensibility and the pilot may fall forward on to his controls; but if he is strapped in sufficiently tightly his hands leave the stick and his feet no longer act on the rudder. Should he be spinning on a stable machine, he may come to himself some miles away flying on a level keel.

Case No. 9. 2nd Lieut., aged 20.

He began flying in February 1918, and obtained his wings in July of the same year. From the first moment he thoroughly enjoyed being in the air, and flew well without discomfort or difficulty.

But, in the middle of July 1918, he was in bed for two days with a short attack of influenza. Four days later he was flying an R.E. 8 when he 'felt faint' at 5,000 feet. He came to himself at about 1,500 feet, to find he was in a spin; he managed to right the machine, but broke an axle on landing.

I saw him in October 1918, after a prolonged period of leave and ground duty. He was then a healthy young man of rather poor physique. Heart and lungs were normal. He could sustain the mercury in the U-tube for 40 seconds. During this test his pulse volume became rather small and the tension poor; the rate, however, was in no way excessive, and recovery occurred within a normal period after the close of the effort. The balance tests were carried out perfectly.

Rotation produced a normal response. On turning ten times clockwise, he rose, deviated slightly to the left, but touched the spot on the table easily. He said he was giddy and that the room seemed to revolve against the hands of the clock, but he was not in any way uncomfortable. Turned in the opposite direction, he deviated slightly to the right; the room seemed to go the same way, but he recovered rapidly. He suffered from no nausea, headache, or other discomfort.

This is the case of a man of somewhat poor physical development who 'fainted' in the air after an attack of influenza.

The next example of this condition is a pilot with long experience and 250 hours war flying in France. He became chronically tired and, at the end of a long patrol, 'fainted' in the air.

Case No. 10. Capt., aged 20½.

He joined in August 1916, and went out to France as a pilot in December of that year.

In July 1917, after 250 hours flying under war conditions, he was returning from a long patrol when he 'fainted' in the air. But, knowing he was going on leave, he said nothing about it and came home on July 28.

After three weeks he was posted to a Training Squadron as instructor. He began to notice that he had lost all keenness for flying and that he 'started at a noise'. One day in December 1917 he was suffering from neuralgia in his face and went up in a D.H. 6. He 'came over foggy and silly', and became unconscious at about 4,000 feet. He 'woke up' at about 1,500 feet and flew the machine back to the aerodrome without difficulty.

He then went to hospital for a fortnight and, after three weeks' leave, returned to his squadron feeling perfectly well. He was extremely keen and thinks he never taught better; he instructed thirteen pupils in a month. He was then transferred to another aerodrome, where he remained for four months. At the end of that time he found he could not stand 'stunting'.

In July 1918 he was given ground duty. He came before me in November because he was anxious to return to flying. He could walk 20 miles without discomfort, and had been playing two rounds of golf daily. At first he noticed that he was off his game; his normal handicap had been 4, he was now playing 8, though improving daily.

When I saw him he was in splendid physical condition, and passed all the respiratory and balance tests perfectly. On opening his eyes, after ten turns clockwise, the room 'seemed to take half a turn to the right and then stand still'. He rose, walked straight to the table and touched well. He added, 'It was just like coming out of a cloud; I felt I was going to pull out at once.' On being rotated counter-clockwise, his sensations were *mutatis mutandis* identical. He experienced no discomfort of any kind.

Evidently this was a case where 'fainting in the air' was associated with exhaustion, consequent on the strain of excessive flying under war conditions. It is interesting to record that this pilot had never 'crashed' since he obtained his wings.

The next case shows that 'fainting in the air' may be the terminal phase of a long period of loss of confidence.

Case No. 11. Capt., aged 27.

This pilot flew before the war in a training school, and was given his wings when he joined up in January 1916.

On July 20 of the same year he suddenly lost confidence under the following conditions. When taking a machine across country he was compelled to make a forced landing in a field. He tried several times to get out, but could not clear the surrounding trees. On landing, after the seventh attempt, he noticed twigs from the trees in the tail and under-carriage of this machine. This brought home to him how near he had been to disaster, and he became so frightened that he left his aeroplane and returned by train. Next day he tried to fly, but failed twice; every little bump 'set my heart going, and I used to wonder if I should come down again'.

He was discharged in August 1916; but in December he began to fly again as a test-pilot. In March 1917 he was given a commission in the

R.F.C., and flew so confidently and well that he was made Flight Commander to a Training Squadron.

On October 27, 1917, he went to France in charge of a section for issuing machines. On December 22 he was testing an S.E. 5, when he 'fainted' at about 5,000 feet. 'Everything seemed to go black all at once.' He recovered himself at about 1,000 feet, but lost consciousness again. He next remembers that he was on the ground, hanging upside down from the machine, which had turned over. He could not release his belt, but was not injured in any way.

After a short stay in hospital, and some months of ground duty, he began to fly again at the end of April 1918. He then became sleepless and frequently suffered from nightmares; these consisted of a recurrent dream that he saw a machine falling without wings. He was never the victim of the accident, but always seemed to be watching some one else falling in this manner.

When he went into the air he felt 'timid' and, if the air was still, he became drowsy. When this sensation came on he felt exactly as if he was 'sitting in an easy chair in front of a warm fire and falling off to sleep'. The 'fainting' came on suddenly, but the onset of the 'drowsiness' was gradual.

He sometimes had this feeling when he played lawn-tennis or billiards, or when he concentrated his attention on a book. We set him to play lawn-tennis under observation, and he was certainly unnaturally slow. When he wanted to take a backhand stroke, he could not bring his racquet across quickly enough to hit the ball. He complained that he found exactly the same difficulty in the air; he could not 'correct bumps', and was 'slow in adapting'.

Up to the time when he 'fainted' in the air he knew nothing of the abdominal sensations experienced by many persons when they descend in a lift. But he then began to be conscious of the 'feeling in the stomach', not only with any small displacement in the air, but also when going down in the lifts of the Tube Railway. He is certain that he never experienced this sensation of 'bumpiness' until February 1918. Since then he has never been free from it with the smallest drop or vertical bank. Moreover, when he had finished a spiral turn, the horizon continued to rush by for a long time afterwards in the direction in which he had been turning. This was another new experience.

When I saw him in August 1918 he was a well-built man of normal appearance, with no tremor of the hands or other signs of disease.

He walked a line and turned badly. He supported himself with difficulty on one leg and could not stand for more than 10 seconds on either foot. He failed entirely to balance the rod on the flat board with his eyes open or closed.

After ten turns in the chair he deviated strongly in the opposite direction to that in which he had been rotated, and did not reach the table at all. He staggered and fell into my arms as if drunk, and said he could not see anything distinctly enough to say in what direction the objects in the room seemed to be moving.

(e) *Comparison of the two reactions, 'Giddiness' and 'Fainting' in the Air.*

Any normal man can be made to suffer profoundly in the air if the rotatory alternations are sufficiently intense, and particularly if the head is held in some abnormal position. For example,

to look upwards at the top plane during a rapid spin is a certain means of inducing giddiness and nausea. In the same way, Major V. B. could provoke at will the preliminary symptoms of 'fainting' by executing evolutions which produced unusually intense rotatory stimuli.

Such reactions are not in themselves abnormal; but, in the examples I have quoted, they could be evoked with undue ease and were unusually violent. Sometimes the disturbance, due to changes in equilibrium, assumed the character of a true vertigo, accompanied by nausea and vomiting. In other cases it consisted of a withdrawal of consciousness, usually spoken of as 'fainting in the air': this does not begin with a true vertigo, but with a feeling like that of passing under an anaesthetic. Surrounding objects grow distant, the 'horizon seems dark', and the actual loss of consciousness may be preceded by a drowsy state, in which it is impossible to act. The final event, as far as the pilot is concerned, depends on the stability of the machine. If it is of a type that passes out of a spin naturally on releasing the controls, the pilot may come to himself to find that he is flying far away from the point at which he lost consciousness; or he may have dropped several thousand feet. On the other hand, with many quick scout machines, which require an active effort before they cease to spin, the result is not uncommonly a more or less severe 'crash'.

Both the true vertigo and the loss of consciousness are the direct consequences of changes in equilibrium. What, then, are the underlying causes of this diversity of reaction? From an analysis of fifteen cases of 'giddiness' or 'fainting' in the air, where I was able to subject the pilot to exhaustive examination, I should like to put forward the following solution.

Out of ten pilots and observers who came under my care for giddiness and vomiting, all but one suffered in this way when they first went into the air; many of them succeeded in adapting themselves more or less successfully to the new conditions, until some factor arose which led to diminished control. They then regressed to the earlier reaction, and adaptation was no longer possible. It is interesting to notice that all nine patients had been unable to swing with pleasure in childhood, and many of them had been habitually sick in the train.[1] As they grew up, they gradually conquered this childish reaction; but, on being exposed to changes of equilibrium in the air, it returned. In most cases it was again brought under control, reappearing, however, with any cause which lowered the general resistance of the central nervous system. In the one case where the pilot had not suffered in the air during the early stages of his training, he

[1] It is interesting to notice the close association of rotatory vertigo and train sickness. For it is obvious that the latter is evoked from the visual apparatus, whilst the former is due to vestibular stimulation. The reaction is identical in spite of the diverse nature of the peripheral excitation. Another example of this order is the giddiness and nausea induced by rotating the walls of the room so that the victim, seated on a chair at rest, obtains an illusion of movement. One of the principal functions of the vestibular apparatus is to maintain the balance of the eyes; if this is disturbed, giddiness will follow although the semicircular canals have remained at rest.

began to vomit after an attack of influenza: this produced severe loss of weight and was followed by a constant feeling of fatigue. He had been, moreover, an unusually nervous child, and was not able to sleep without a light until he was sixteen years of age.

Giddiness and vomiting in the air are an expression of undue susceptibility to changes in equilibrium. This is usually constitutional; it may be so severe that it can never be corrected (No. 3), but in most cases adaptation is possible. The tendency to be giddy in a swing or to vomit in a train are overcome on the passage from childhood to adult life: in the same way, the reaction to disturbances of equilibrium may be controlled with the gradual acquisition of facility in the air. But any disturbance, physical or mental, associated with diminished general resistance in the central nervous system, will cause regression: the patient reverts to his original mode of reaction.

On the other hand, none of the five patients who 'fainted' in the air suffered from any discomfort on learning to fly: all enjoyed it from the first. Not one of them had ever been giddy in a swing or suffered in childhood from train-sickness. Evidently they were endowed with the power of controlling the effects produced by changes of equilibrium on the vestibular apparatus; vertigo, with its accompanying nausea, was absent. But when the impulses from the semicircular canals became too violent to be held in check they expended themselves by producing a withdrawal of consciousness. This begins with a narrowing of the field of attention, which may culminate in complete oblivion. Such a reaction may make its appearance in normal pilots, provided they push the rotatory stimuli up to unusual limits, as was the case with Major V. B. during his technical experiments. But under the conditions of normal flight fainting in the air at low altitudes is always evidence of diminished general resistance. Sensory impulses, which should be controlled, become capable of evoking an abnormal general reaction. This may be due to stress of war-flying (No. 10), to fear and anxiety (No. 11), to some gastro-intestinal condition (No. 8), to the after-effects of influenza (No. 9), and probably to a multitude of causes which act in a similar manner.

But amongst the group of pilots who faint in the air, the natural resistance to vertigo is high: the impulses evoked by disturbances of equilibrium do not show themselves, therefore, in giddiness and nausea, but in a disturbance of consciousness.

This difference in reaction to changes of equilibrium in the air can be demonstrated by observations on the rotating chair. The effect produced upon those who were 'giddy' in the air was in sharp contrast to that produced in the group who had 'fainted'. Of the ten who had been 'giddy' and vomited, nine reacted excessively to rotation in the chair; they became more or less giddy, sweated, and suffered from nausea. The actual form assumed by the physiological response was not abnormal, but it induced an excessive general reaction with undue ease. In one instance only was this not the case: he had been shot down in aerial combat and his regression was assuming an almost pure psychopathic form.

On the other hand, of the five pilots who had 'fainted' in the air, three suffered from no discomfort of any kind after rotation in the chair; in two cases 'everything went misty'; and both patients complained that they felt exactly as they did in the air.

It would seem as if those who have a natural tendency to become giddy on rotation, react to disturbances of equilibrium with nausea and vomiting. Others can dominate the vertigenous aspect of the impulses from the semicircular canals; in them rotatory stimuli, if sufficiently severe, evoke the condition known as 'fainting'. How far the tendency of the reaction to assume this form depends on a predisposition to react to any severe shock by cardio-vascular disturbance, must be determined by future research. It may be found that even the 'fainting' induced by lack of oxygen is the same reaction of the central nervous system to stimuli of an entirely different order. My cases, however, are too few in number to afford an answer to this important question in applied physiology.

Wider experience may show that there are other forms of reaction which may occur in the air. Physiological responses are not inevitable and rigidly-defined manifestations. Such a case as No. 8 shows how closely related are the two reactions, 'fainting' and 'giddiness' in the air; for although the patient is classed under the first heading a violent dive on to a ground target induced nausea and many of the symptoms of 'giddiness'.

(*f*) *Attacks of minor Epilepsy in the Air.*

In the early days of the war, before we were familiar with the pathology of 'fainting' in the air, some neurologists attributed the condition to minor epilepsy. But further experience has shown that this must be an excessively rare cause of pathological states in the air. I have met with one undoubted instance only; but the symptoms form such a striking contrast to the commoner form of flying disability, that the case seems to me worthy of record.

Case No. 12. Sergeant-Pilot, aged 24.

He joined the R.N.A.S. in September 1914, and went to Egypt in June 1915. Very shortly after his arrival he was seen by the Medical Officer in an attack of minor epilepsy. He returned to England and was discharged on August 15, 1915, with this diagnosis.

He then learnt to fly at his own expense, and applied for a commission in the R.F.C.; he was, however, rejected on his previous history.

But in September 1916 he succeeded in joining without a Medical Board and, after passing through a theoretical course, went to a squadron as 2nd air mechanic. Here he rapidly learnt to fly, and gained his wings after about 20 hours in the air.

In March 1917 he went to France, and had his first and only severe accident in May of that year. He was flying a Sopwith two-seater. All he remembers is that, on rising 300 to 400 feet from the ground, he suddenly felt his arms and legs growing 'powerless' and he lost consciousness. He does not remember hitting the ground; but not more than a few seconds later he climbed out of his machine and helped his observer who was hurt.

He had no conception of what had happened, and says he felt as if he were a spectator, who had come to the rescue.

He did not fly for three weeks and then went to another squadron in France as a test pilot; there he remained for six months. He had no trouble in the air, but one evening, when walking with a friend he suddenly became unconscious and fell to the ground.

In March 1918 he came to England and acted as ferry pilot; but he had many small attacks on the ground, and in September had a severe seizure in the street. He fell and became absolutely unconscious; he remembers walking on the pavement and then found himself in a tramway car with 'people fussing round' him.

He has been subject to these attacks ever since he was about 14 years of age. He 'suddenly loses count', becomes dazed, and then recovers to resume his work as if nothing had happened. When in the street he has dropped things from his hands and walked on oblivious of his loss. He has never wetted himself or bitten his tongue.

In 1911 he had an attack whilst riding a motor bicycle. This led to a bad spill, and he severely injured three fingers of his left hand.

He enjoys flying intensely, and never feels better than when he is in the air. A long period of ground duty makes him depressed, and leads to a considerable increase in the number of the attacks. He has had one 'crash' only; but sometimes on long journeys, when acting as a ferry pilot, he has 'felt queer' in the air. He has always been fortunate 'to be high enough to come to myself all right, though I have lost height several times'.

One brother and one sister have similar attacks, and his father, who died of pneumonia, drank very heavily. The patient himself is a teetotaller.

He was a well-built rather nervous-looking man. His heart was normal, and the pulse showed a perfect reaction to measured effort, returning with normal rhythm in one minute and a half.

His hands showed some irregular tremor, and his tongue was not steady. He could stand on either foot for 15 seconds on the first attempt, but could not balance the rod on the flat board, either with the eyes open or closed.

The pupils were of medium size but oscillated widely when his eyes were fixed on a distant point. The reflexes were normal, and there were no signs of gross disease in the nervous system.

This case differs from all those previously described in this chapter by the fact that the attacks occurred before the patient took up flying. Moreover, the majority happened on the ground and were associated with the usual manifestations of minor epilepsy. With care it should not be difficult to exclude even epileptics of this class from the Flying Services.

(*g*) *Conclusions.*

Giddiness, vomiting, and fainting in the air may occur from many different causes apart from physical or chemical deficiencies in the atmosphere.

Candidates who show any signs of disease of the ear, nose or throat, are excluded from the flying branch of the Air Force. But the most careful examination cannot ensure that the pilot will not suffer from inequalities of tension in the middle ear on rapid changes in altitude. This is particularly liable to

occur if a cold or sore throat leads to partial or complete blocking of one or other Eustachian tube. This temporary change in the conditions of tension, external to the labyrinth, is a potent cause of giddiness, especially in scout pilots engaged in war-flying. It is characterized by the fact that it continues for a time on the ground after landing and is frequently associated with pain (Sydney Scott).

But there are many cases of giddiness and fainting in the air which bear no relation to abnormal conditions of those portions of the auditory apparatus external to the receptive nervous mechanism.

Any normal man can be made giddy during aerobatic evolutions, such as spinning, if he holds his head in certain unusual postures. We can bear with impunity certain violent disturbances of equilibrium if the stimulus is expended on certain parts of the vestibular apparatus, but not if it falls on other combinations of the semicircular canals. In the same way, provided a normal pilot is not unduly susceptible to giddiness, he can induce at any rate the preliminary stages of fainting in the air by pushing rotatory stimulation experimentally to abnormal limits.

But machines are so constructed, and pupils are taught to carry out aerobatic evolutions in such a manner, that the majority of normal men do not suffer from these symptoms in the air. There are, however, some in whom the physiological response is so violent that it can never be overcome, and they are always giddy and nauseated whenever there is any sudden or considerable change in equilibrium. Others suffer at first, but may overcome the reaction as they acquire facility in the air. Such persons are liable to regress under the influence of any condition, physical or mental, associated with diminished central control.

The majority of these patients could not swing with comfort in childhood and habitually suffered from train-sickness. When rotated on a chair the larger number were uncomfortable and suffered from nausea and sweating.

On the other hand, the pilots who came under my observation for 'fainting' in the air had all enjoyed flying from the first. They had experienced no discomfort in childhood, either when swinging or when travelling in the train. In two out of the five cases I was able to evoke that 'mistiness', which is one of the preliminary stages of fainting, by rotation in the chair; the others showed no abnormal reaction to this method of stimulation.

Epilepsy is one of the rarest causes of 'fainting' in the air. One definite case only has come under my observation during the later stages of the war, since the institution of a strict medical examination for admission into the Air Force. This is reported on p. 29. Differential diagnosis should not be difficult, for in this case, as might be expected, the larger number of attacks occurred on the ground under conditions that excluded any form of vertigo.

D. Sensations experienced by Normal Persons in Machines heavier than Air.

(a) *Introduction.*

Balance in the air or on the ground depends primarily on the character and intensity of many diverse sensory impulses. Changes in the posture of the body as a whole affect the vestibular apparatus, the spacial aspects of vision, and the afferent mechanism of joints and muscles. If these various sense-organs function normally, the basis is given for those actions necessary to ensure stability, whether on the ground or in the air. Any external condition which produces an abnormal series of responses in any part of this complex sensory mechanism will lead to defective equilibrium. Giddiness, due to unregulated tension in the middle ear, and the disastrous effects of heterophoria are examples of such aberrant stimulation of normal sense-organs.

If want of balance were merely a matter of irregular external stimuli, or of some defect in the peripheral sense-organs, the question would be easy of solution. But I have been able to show that an abnormal reaction may be caused not only by faulty sensory impressions but by lack of what, for want of a better word, may be called 'higher control'. A man's 'muscular sense' may be perfect; and yet, when his eyes are closed, he may be unable to stand on one leg or to balance a rod on a flat board. His vestibular response, when rotated on a chair, may be normal, but the sensory impressions evoke nausea or the preliminary stages of fainting. Two factors must be considered in all observations on sensation, the character of the primary response and the nature of the final reaction.

Moreover, physiologists have long been familiar with the fact that a constant physical stimulus does not evoke in every case an identical physiological response. More mechanically-minded investigators are accustomed to assume that a strictly regulated physical stimulus must be followed by a directly proportionate functional response. On this hypothesis a body at a certain temperature should always produce an identical sensation of heat or cold; but this is notoriously not the case. A temperature of 30° C. may seem at one time hot, at another cold, according to whether the hand has been previously soaked in cold or in hot water.

Again, the impression produced by a physical stimulus, however carefully selected, is not of necessity simple, but is frequently extremely complex. It may evoke impulses which are incompatible with one another from the sensory point of view. Thus a temperature of 45° C. stimulates the heat-, the cold-, and the pain-spots; normally it produces a sensation of heat. If the mechanism for the reception of heat-stimuli is absent, 45° C. seems to be cold: if the part is insensitive to both heat and cold, pain alone follows the application of this temperature although it normally excites pleasant heat. In this case a physically simple stimulus evokes complex and incompatible

impulses, which must be sorted and integrated before they can form the underlying basis of a sensation.

Even then the struggle is not over. For it may happen that the mind is not at the moment attuned to accept a sensation of this kind: it is therefore suppressed, and does not enter the focus of consciousness. Under such circumstances some other group of sensory impressions may become dominant, to the exclusion of those more naturally anticipated. For example, we all know how certain forms of toothache are relieved by taking food. The physical cause of the pain is not influenced by the mechanical act of deglutition: but the neuralgia is inhibited for a time by the massive impulses poured into the central nervous system from the upper gastro-intestinal tract.

An identical stimulus can evoke in the same individual a varying response; what wonder that the action of the same physical forces may produce the most diverse effects upon different people. A good example of such differences, drawn from daily life, is the sensation produced by descent in a lift. Many people experience a peculiar 'sinking in the stomach' or 'feeling as if my stomach was being left behind' when moving downwards. Others have never been conscious of this sensation, unless the lift moves with a rapidity unusual in this country. Between these two extremes lie those who recognize this 'feeling' if the movement starts somewhat suddenly, but not under ordinary conditions. This sensation, like giddiness in the air, can be acquired. One young pilot knew nothing of any such 'feeling in the lift' until after an attack of influenza: the first time he travelled on the Tube Railway, on recovering from his illness, he noticed that the descent of the lift produced a peculiar effect he had never experienced before. When he returned to duty ten days later he found he had lost all confidence in the air and was 'gripping his controls tightly and tensely'.

Thus between the impact of the physical stimulus on the sense-organs and the final production of a sensation, lie innumerable possibilities of variation in the physiological and mental reactions. What wonder that the sensations induced by flying a machine heavier than air differ fundamentally in different persons, though the stresses and strains may be identical.

These individual differences start from the moment the machine leaves the ground. In some the uncomfortable bumping, caused by 'taxy-ing' across the aerodrome, gives place immediately to a feeling of profound security. If the passenger is strapped in with a well-fitting belt and his pilot is expert in correcting 'bumps', the machine seems to be the stable centre of the universe; it is the earth and sky that shift and move. A vertical bank produces no sensation beyond the feeling that the country with its roads, woods and houses is tilting in a peculiar and definite manner. Even during a flat spin it is the horizon that races round like the rim of a rotating bowl. An expert pilot talks in terms of a moving universe: he says, 'I came out to find the earth rushing up and so I pulled my stick back'; or 'My horizon was crooked, so I knew I was flying one wing down'.

In those who are fortunate enough to experience this stability from the first, it transcends any security obtainable on earth or sea. But many first-rate pilots have been frightened and unhappy on their first flight; they cannot believe that any one felt secure from the first moment he left the ground. With them confidence is acquired. But since it has been gained by practice it can also be destroyed by any condition which lowers bodily or mental vigour; and this is the case, not only with those who have adapted themselves to conditions in the air, but also with those in whom such confidence is innate.

Any experience which induces anxiety or fear may destroy the confidence of even the finest pilot. To be shot down in aerial combat, or to land in flames, is sufficient to upset the sense of security in any one, and may lead to subsequent want of adaptation to changes of equilibrium in the air. But should the concussion produced by the 'crash' abolish all memory of the events directly preceding the accident confidence may remain unimpaired. For this reason some who have passed through a terrifying experience can subsequently fly as well as ever. It has left no trace on the memory; the whole episode, including perhaps events of some hours before the ascent, has been entirely wiped out.

On the other hand, the sudden realization of danger may destroy all feeling of confidence on the spot (No. 11). The pilot not only feels himself insecure, but may become clumsy in his actions and suffer from abnormal sensations in the air. The anti-aircraft guns of the enemy produced more harm by undermining confidence in the air than by the actual destruction of machines: for when a pilot began to dream of 'Archies', he was near the end of his flying career at the front.

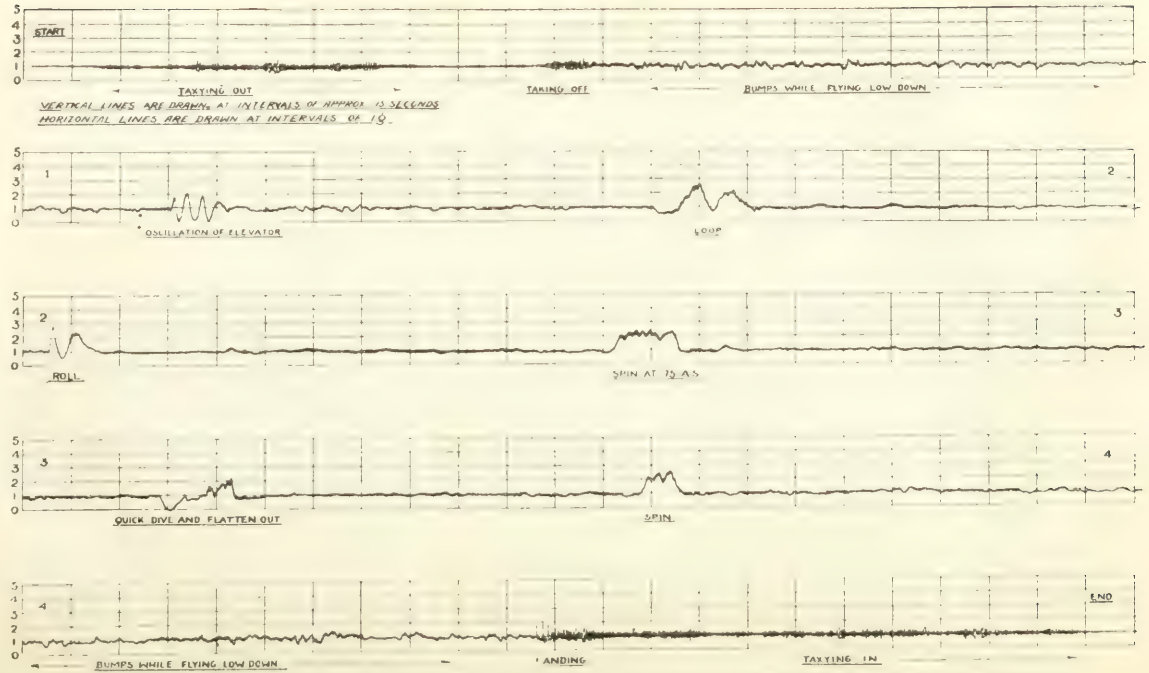
(*b*) *Actual Experience during Aerobatic Evolutions.*

It is a matter of everyday experience that the same physical stimulus does not produce an identical effect on different human beings. But the physicist finds it hard to believe that the strong mechanical forces in action during aerial flight may lead to no conscious effect: and yet from a physiological point of view this might have been exactly anticipated. The more perfectly the passenger feels himself part of the machine, the more he will tend to translate changes of posture into some alteration in the position of surrounding objects. Stresses and strains disappear so long as there is perfect physiological adaptation to changes in equilibrium. In this way we gain a rapidity of action which would be impossible if every physical alteration entered consciousness and necessitated a corresponding action of the will. A good pilot does not fly by rule nor does he depend entirely on his instruments. When he wants to 'bank' he says, 'I just lean over and it comes,' exactly as when rounding a corner on a bicycle.

The following figure gives the actual forces to which the machine is exposed during various evolutions, as shown by means

VARIOUS MANŒUVRES ON A BRISTOL FIGHTER

29·3·18



(Reproduced from the Reports and Memoranda, No. 469, of the Advisory Committee for Aeronautics, by permission of the Controller, H.M. Stationery Office.)

of the accelerometer.[1] From this beautiful record it will be seen that a 'zoom' leads to a rapid drop to 0, followed by an irregular rise to 2 g,[2] just before the machine flattens out.

On looping, g first drops a little, then increases rapidly almost to 3, falls and rises again to about 2. A roll gives a similar but shorter rise, followed by a fall and a second flat-topped curve.

In spinning g runs up and oscillates round about 2, dropping quickly, when the machine is pulled out of the spin.

The actual sensations experienced by a passenger during these evolutions were determined independently by four medical observers. Colonel Birley, principal medical officer to the Headquarters of the R.A.F. in France, made a long series of experimental investigations from the back seat of a Bristol Fighter. These form the basis of the inquiries summarized in this chapter. To Captain Rippon, medical officer to the 29th T.C.S. (the 'Medical Flight'), I am indebted for much personal experience of flight under varying conditions. Mr. Sydney Scott has also given me valuable information, especially with regard to giddiness and analogous sensations. Lastly, I have myself experienced, in an Avro, the effect of all these evolutions.

The whole matter was then discussed with a series of pilots, particularly with Major Bird, D.S.O., and his colleagues of the 'Medical Flight', who are accustomed to observe their own sensations and to listen to those of their pupils. To them my sincere thanks are due for their patience, and for the remarkable way in which they worked out these problems for themselves.

Most pilots, however, are not good witnesses in such an inquiry, unless their reactions are in some way aberrant. A normal pilot is so busy flying his machine, and is so instinctive in his reactions, that he has neither time nor attention to observe his own sensations. On the other hand, the four medical men who went up as passengers were not only trained observers, but were intent on discovering the effect produced by each evolution in turn.

In contrast to the evidence yielded by these normal individuals stands that of Captain H., a most skilful pilot, who returned from France, after six months' flying under war conditions, owing to nausea and vomiting. He was engaged on

[1] Report on the Measurement of acceleration on Aeroplanes in Flight, by G. F. C. Searle and W. Cullimore, June 1918.

[2] g is the symbol used for the acceleration per second of a body falling freely under gravity.

The weight is the mass multiplied by g.

Forces are proportional to the accelerations they produce on the same mass. Thus we may express the relative magnitudes of the forces acting on a body in terms of the accelerations these forces are producing.

The record (Fig. 1) gives the resultant force acting on any mass within the aeroplane in terms of the ratio of the acceleration that force can produce to the acceleration (g) which would be produced by gravity, acting normally. Thus, when the force registered is 1, it is exactly equal to that of gravity.

The supporting force of the seat, when sitting normally in a chair, is equal to g; seated in an aeroplane it is equal to g, multiplied by the number on the record, the value of which depends on the nature of the evolution being carried out. It is usually spoken of as 'one, two, or three g'. The excess or deficit above or below the value of g may be considered the measure of the abnormal physical forces acting on the body.

mechanical experiments in the air for the technical branch, and gave valuable evidence before the Committee on Accidents, especially in answer to my cross-examination.

Lastly, my thanks are due to Major V. B., another officer engaged in technical experiments, who was able to produce fainting in the air by excessive disturbances in equilibrium. He supplied me with many interesting details.

(i) '*Zooming*'. During this evolution the machine is dived steeply and then rises almost vertically in consequence of the great acceleration of momentum. Sometimes on quick-flying scouts the preliminary descent may be eliminated: the essential part of the 'zoom' is a steep climb. This throws an enormous strain on the machine and exposes the pilot to violent changes in stress.

All the medical observers, however, failed to notice any sensation during this manœuvre, and the three pilots of the 29th Training Squadron were of the same opinion: but they added that there was a sensation 'as if you were loose on your seat', when flattening out on the top of the 'zoom'.

On the other hand, Captain H. insisted that he felt his 'head being squashed into his body'; 'you feel you are being forced into your seat and it is impossible to move your legs though you can move your arms.' Here we find the first flat contradiction in testimony. Four highly-trained scientific observers and three pilots chosen for their perfect adaptation to conditions in the air, failed to perceive any sensation until the end of the manœuvre. On the other hand, a skilled pilot, with technical knowledge of a high order, who suffered from nausea in the air, was acutely conscious of the physical forces acting on his body during this evolution. In fact he said, 'If I were to lose this sensation, I should be worried, because then I might be putting forces on to the machine which would break it'.

Major V. B., the technical pilot who could make himself faint by carrying out certain experimental evolutions, was in complete agreement with the majority of the observers. He said that during a 'zoom' he 'felt nothing except the joy of doing it'.

Thus it is evident that what we call perfect adaptation to disturbances of equilibrium in the air is associated with control by the central nervous system of the various afferent impulses, evoked by the action of intense physical forces on the human body. Should they be permitted to rise into consciousness and cause sensations during normal flight, the pilot tends to suffer from giddiness and nausea when they reach any considerable intensity.

(ii) *Looping*. None of the medical witnesses experienced any giddiness or definite sensations during an ordinary loop, and the three pilots of the 29th Training Squadron agreed with these observations. Colonel Birley noticed that, after the fourth or fifth consecutive loop, a sensation gradually came on of 'being loose in the seat'.

As might be expected, the account given by Captain H. again differs profoundly from that of the other observers. He feels that his head is being squashed into his body; as if he were

being forced into his seat. 'It is impossible to move your legs although you can move your arms freely.' This alternates with a feeling of 'decreased gravity': 'it makes me feel as if my stomach was coming up. I sweat and may have nausea. I have put my head over the side but have never been sick.'

Major V. B.'s experiences are particularly interesting. He feels no sensation whatever during a perfect loop, but if he makes a short loop, a mist comes before his eyes like the early stage of going under an anæsthetic. If he makes five or six perfect loops consecutively he loses his horizontal and comes out to find he is flying wing down. 'You haven't the power to get her right unless you can get your head clear again. Something goes wrong after the third or fourth loop, which spoils their perfection.'

Here again we see the same difference in central control. In perfectly adapted persons simple looping produces no sensation, whilst Captain H. was sensible of the physical forces acting upon him throughout. These sensations came to Colonel Birley after a fifth or sixth consecutive loop only, and then in a mild degree. Major V. B. experienced nothing unless the loop was imperfectly performed, when he felt in a slight degree the preliminary sensations of fainting; a series of perfect loops disturbed his power of flying horizontally unless he made a definite corrective effort.

(iii) *Spinning.* The effect produced by spinning in normal persons depends greatly on the position of the eyes and head. Pilots vary profoundly in the attitude they adopt; some keep their eyes on the instrument board and do not look outside the fusilage, others fix some point on the ground. Many pilots contend that if the eyes are thus directed throughout 'you remain conscious of your position in space, but if you look inside the fusilage you don't'. Both are safe methods and should not cause giddiness in normal persons.

Colonel Birley, who has made many observations to investigate this point, found that when he looked downwards during a spin he knew his position in space, but was conscious of forced movements. Thus, when spinning to the left (counter-clockwise), it would have been an effort to do anything to the right.

However well adapted a pilot may be to rotatory stimulation, he suffers from giddiness and frequently from nausea if he looks up at the top plane during a spin. Colonel Birley found that, on looking up, he 'lost himself entirely' and suffered from acute vertigo. 'I could not have done anything, and should have been incapable of all effort.' He was not, however, nauseated. Looking at the wing-tip is said by some to be even worse, and to be spun facing the tail is worst of all.

The account given by Captain H. is most instructive. During a spin he always looks straight forward at his instruments, and never lets his eyes wander outside the fusilage. On emerging from a spin he does not know where he is, but 'pulls out by rule'. He then finds that the 'horizon is crooked'. 'Something inside me would make me fly the machine one wing down.' During one set of experiments he looked up obliquely to the

left in order to count the turns by means of the sun, and was extremely uncomfortable. When he came out of the spin he was reading his instruments with great difficulty. 'I forced myself to do it; but it was a jolly big effort.' After coming out he stalled the machine badly and then dived; this was an unintentional manœuvre due to his state of mental confusion. He did not suffer from giddiness, but after it was all over felt sick. 'I felt bunged up and was unable to think clearly; I couldn't reason.' He is so familiar with this state that he has learnt by heart and repeats to himself exactly what he has to do. 'so that I mayn't have to think it out at the time'.

During these same experiments he carried out several more spins and nearly vomited. 'I felt something, under my lower jaw-bone, was being drawn upwards, and whenever I have felt this before I have always been sick. In this case I put my head over the side: but the drawing-up feeling below the tongue grew less and finally disappeared. I was not sick, though the feeling of nausea persisted for some time after I landed. I was very sick during the following night.'

Major V. B., a highly expert pilot, had the following experience whilst carrying out some experiments for the Technical Department. After an unsuccessful attempt to discover the smallest horizontal banked circle in which a Sopwith triplane could be spun, he got the machine into a turn at 3,000 feet. On starting the second turn 'the sky appeared to go grey'. 'A mist gradually arose like going under an anaesthetic,' and he 'fainted'. It was not an unpleasant sensation. When he came to himself, he was flying over a village about a mile away from the place of the experiment. The unconsciousness must have lasted about 20 seconds. During the first turn g reached 4·5, during the second 4·6. The turn was of about 140 feet at a speed of 114 miles an hour.

This pilot found experimentally that, whenever the acceleration (g) was pushed up to a high figure, he experienced the characteristic darkening of the sky which was preliminary to fainting. On another occasion he was looping and diving a D.H. 4 during a mock fight, when these preliminary sensations reappeared. He realized his danger and struggled against losing consciousness. First came a feeling of pressure in the head: then a mist gradually approached and spots rose before his eyes. He felt faint, chiefly at the bottom of the loop, and was quite conscious at the top. Then 'daylight' returned during the dive, and he came down about three minutes later feeling perfectly well. This preliminary sensation is distinctly pleasant, but is associated with inability to make an effort; 'it requires a definite struggle to right the machine.'

(c) *The Human Element in Aeroplane Accidents.*

(i) *The Physiological Effects of disturbances of Equilibrium.* Normal human beings differ profoundly both in the intensity and in the character of their reactions to changes in equilibrium. Rotation in a chair, with the head erect and the eyes closed, is

usually followed by a tendency to deviate, and, on opening the eyes, surrounding objects seem to be moving in a direction opposed to that of the rotation. Thus, if a normal man has been turned clockwise, the apparent rotation of the room goes counter-clockwise, and the deviation takes a form determined by the position of the head during the turning. The average human being in perfect health rapidly overcomes these after-responses, and recovers his stability in a few seconds; moreover, he does not suffer from nausea or other abnormal sensations.

Such a patient as No. 3 (p. 190) was classed as abnormal, although he was in perfect physical health, because he invariably became giddy and was incapacitated by stimuli to which the majority of men could adapt themselves without difficulty. Such a classification is, however, purely arbitrary. Aeroplanes are so constructed that they can be flown by any healthy young man without producing vertigo or other disturbing symptoms: it would be possible to build 'freak' machines that required the talents and training of an acrobat to resist the giddying effect of their evolutions. Thus the criterion by which we judge whether an aviator is normal or abnormal depends ultimately upon whether he can adapt himself to those disturbances of equilibrium to which he is commonly exposed in the air.

Giddiness and forced movements are not uniformly proportional to the rotatory stimuli acting on the body. For exactly the same physical forces, which produce intense vertigo when looking upwards, may be without effect if the head is held in the usual position and the gaze is directed horizontally forwards. This can be shown by the following experiment. Whilst standing in the normal position, rotate the head rapidly from side to side; most persons experience little or no vertigo. But, if the eyes are directed to the ceiling and similar lateral movements are carried out, the majority of healthy people become giddy and rock on their feet. The physical forces are the same in both cases; but in the former they are exerted with the head in its usual posture, whilst in the latter the position is one to which we are not habitually accustomed. In the same way even a normal pilot can be made profoundly uncomfortable by looking upwards during a spin.

An even more insidious danger is the mental state which accompanies the physiological changes induced by rapid rotation. Colonel Birley found that, when he was spun counter-clockwise with his eyes fixed on a spot directly below him, it became difficult 'to do anything' to the right; if he looked upwards during the spin, he became incapable of all voluntary exertion. Sydney Scott came to the conclusion that some persons do not come out of a spin because they cannot realize that they must make a definite mental effort to pull the machine into a state of normal stability. Several pilots of experience bore out this suggestion. One of them said that in putting on the rudder to stop a spin he is reluctant to substitute 'a state of strain for a state of ease': his tendency is to continue spinning too long. Another spoke of this condition as a 'sort of mental coasting'. Major V. B. was particularly explicit on this point; he has been

throughout so conscious of the danger of this pleasant mental state that, as soon as he feels it beginning, he cuts short the manœuvre.

So long as the machine is one which will come out of a spin when the controls are released, the pilot may become unconscious and yet no accident happen. But if a definite act is required to terminate the rotation, as on a Camel, it is obvious that the machine may spin into the ground because the pilot has been rendered incapable of the necessary voluntary effort. The more rapid the turns the more likely is it that this condition will be induced: and it is not improbably responsible for some of the accidents on very delicate scout machines such as Camels. Where, however, the pilot is seen to fall into a spin, to come out again and to spin into the ground in the opposite direction, it is possible that forced movements are responsible for the reversal of rotation after the first recovery.

(ii) *Regression.* Flying, like the ability to play games, is definitely acquired and maintained by practice, and the measure we apply to all such human activities is the extent of functional efficiency. Now all action is based upon reflexes, which are controlled by the activity of higher centres: these in turn are dominated from above, and the active life of the central nervous system is comprised in a hierarchy of functions. Finally, consciousness stands as commander-in-chief over a vast number of subordinate activities, each of which is itself in authority over some more lowly mechanism.

To refer everything to the central authority would be a slow and laborious method of action; power is therefore delegated to the various departments to act without reference to the central administration. The lines of action are, however, laid down from above; we acquire a new aptitude by conscious effort excited through lower motor and sensory mechanisms. When learning to play the piano the fingers are laid consciously on each key and a complicated apparatus is thrown into action which strikes the note. Soon, with practice, the fingers move automatically and consciousness is occupied in reading the musical symbols on the printed page. Finally, with increased facility even this becomes almost automatic; the expert musician scarcely sees the page, for the nature of the musical phrase suggests to him the sequence of the accompanying harmonies.

First, the mechanical apparatus must function perfectly: the strings must be in tune and the levers which move the hammers perfectly adjusted. The fingers must learn to strike the right keys and the two hands be co-ordinated and controlled. This after long practice becomes automatic. At the same time there must be perfect comprehension of the musical notation and strict combination of mind and hand. Finally, in the supreme state of functional aptitude, the printed page suggests a musical thought which is automatically manifested as a series of sounds.

In the same way the aviator slowly acquires increasing facility in manipulating a complicated apparatus. At first he laboriously flies by rule and has to memorize the steps by which each evolution is induced. As he becomes more expert he has but to desire

some movement and it occurs; for a good pilot flies automatically and not by formula. He corrects, and may almost be said to anticipate, 'bumps' by instinct.

This power over the machine has been gained by conscious effort, during which a series of functional adaptations become engulfed in the automatic activities of the central nervous system, as soon as they are acquired. Movements laboriously learnt become unconscious reactions. But this supreme control can only be maintained by constant exercise and perfect physiological efficiency. Any influence which tends to diminish the power of concentration or to disturb the acquired mastery over sensory and motor impulses will lower ability to fly. The pilot becomes aware that he has lost his certainty in landing or is inclined to make flat turns. He does not know why he is no longer master of his actions, and complains 'I do everything that used to make me land perfectly, but it only comes off once in three or four times'. Like a golfer, he is 'off his game'. He does not know what is wrong because, when perfect facility has been acquired, the act has become automatic.

It is a well-known physiological law that when the control by a higher centre over some lower activity is diminished the character of the reaction tends to take on a more primitive form. The lower centres released from control are free to exercise their activities unchecked. For example, in hemiplegia the paralysed arm is frequently in a condition of great rigidity. This is due to the loss of that control usually exercised by the cortex of the brain over the lower motor centres. In the same way removal of the dominant influence of the sensory cortex on the afferent activities of the optic thalamus causes the paralysed half of the body to become over-sensitive to all painful or pleasurable stimulation. This phenomenon is usually spoken of as the 'release' of lower centres.

Here one crude structural centre of later development dominates another with more primitive reactions. But a similar law governs the inter-relation of a series of functions, each of which has been in turn acquired by practice and conscious effort. On the piano the fingers must first be taught to strike the right keys; then the two hands must work in a co-ordinate manner. As each new facility is gained it becomes automatic and disappears from the focus of consciousness. But with loss of control, movements once performed without thought require an effort of attention, and both mind and hand make apparently inexplicable mistakes. If the error takes the form of some fault previously overcome by practice we speak of 'regression'. The sufferer has fallen back on some previous method of reaction.

This unexpected return to some previous habit is one of the commonest human errors in all mechanical activities. Innumerable instances can be gathered from games and from daily life. A man who has driven a motor-car with the levers to the left, and then becomes habituated to the more ordinary form with a right-hand brake, may find in an emergency that he is groping to the left. A golf-player who is 'off his game' finds that he has fallen back to some long-conquered fault. This might be called

mechanical regression; some action, which has been acquired in perfection and has become automatic, may be disturbed by failure of control and is consequently carried out in an inferior manner.

But regression may be manifested not only in a motor act, but also on the sensory side. A tendency to giddiness in the air may be overcome with the acquisition of aptitude to fly. The physical stresses and strains to which the pilot is exposed remain the same, but the afferent impulses they cause are integrated and controlled. If, however, the general physiological resistance of the nervous system is lowered, or the power of mental concentration diminished, sensations of unusual intensity may be aroused accompanied by giddiness and nausea. A pilot may regress to the form of reaction which troubled him when he first went into the air.

The war has furnished frequent examples of the mental aspects of regression. A soldier is sent home suffering from the stress of fighting; he complains of horrible dreams, which take the most diverse and individual forms. Night after night he wakes in fear. But after suitable treatment these terrors cease and his dreams are occupied with the petty worries of the day. Suddenly all the old horrors return in consequence of some great sorrow or anxiety, such as the death of his wife or illness of a child. He has regressed to a previous psychical reaction in consequence of diminished mental control.

Not uncommonly all aspects of regression are manifested in the same patient. A pilot finds he is no longer flying with certainty; he is obliged to think of what he is doing instead of carrying out the manœuvre automatically. This frightens him, and the fear causes widespread regression. He may become giddy or faint in the air, and will probably 'crash' unexpectedly. He complains of frequent nightmares: these may be concerned with horrible events, previously forgotten, which occurred when he served in the trenches. Or he may be haunted by visions of a machine falling in flames, the reappearance in symbolic form of an old fear on first flying over the lines.

Thus regression may lead to the loss of mechanical aptitude, to an abnormal reaction due to the uncontrolled activity of sensory impulses, or to the reappearance of some less efficient form of mental activity. It is of profound theoretical interest, and probably explains certain apparently incomprehensible accidents in the air.

E. General Summary.

1. Conscious stability and comfort in the air depend primarily on the normal response of three groups of sense-organs. These are the vestibular apparatus, the eyes, including the eye muscles, and the proprio-ceptive system with its endings in muscles, tendons, and joints.

But of all the afferent impulses evoked by the impact of physical forces on these various mechanisms, those underlying the projected aspects of sensation are alone of significance in the

present inquiry. We are interested in those impressions which lead to recognition of the position of the body in space.

2. Defective responses from any one of these afferent end-organs will disturb the sense of equilibrium in the air, and may lead to actions that affect the stability of the machine.

3. No candidate for service in the R.A.F. is accepted who shows gross abnormality of any one of these primary organs of sensation.

But in the course of flying a machine heavier than air, an otherwise healthy man may suffer from disorders of vestibular and visual sensibility due to temporary causes. He may not be able to regulate the tension in the middle ear with sufficient ease during a rapid descent and consequently becomes giddy; or his eye muscles may no longer function strictly in unison, and he may develop heterophoria with its resultant lack of visual orientation.

4. The tests at present in use by the Examining Boards for estimating the sense of balance may reveal the existence of some abnormal functional state, but are not otherwise an indication of ability to fly.

5. Standing on one foot with the eyes closed, walking a line heel to toe, and balancing a rod on a flat board, are not tests for 'Muscle Sense' or 'Vestibular Stability', in the class of young men from whom the pilots and candidates of the R.A.F. are drawn. Failure to pass these tests, however, indicates some want of afferent or efferent central control.

6. The presence of Tremor, especially of the hands, is of great importance; it points to some distinct defect in static control, and is definite evidence of disordered function.

7. In some men, otherwise normal, rotatory stimuli produce a more powerful reaction than in the majority of their fellows. They become giddy easily. As children they could not swing with pleasure, and some of them were habitually sick in the train. Such persons are not suffering from a pathological condition: their disability arises from the fact that sensory impulses from the semicircular canals are not checked and controlled to the same extent as in the majority of healthy individuals. Consequently, when exposed to disturbances of equilibrium to which a normal man would adapt himself unconsciously, they suffer from discomfort, become giddy, and may even vomit in the air.

8. Many who were giddy when first exposed to acrobatic evolutions, succeed in conquering this disability. They learn to fly with ease, and the acquisition of this new facility is associated with control of the primary afferent impulses from the auditory and visual apparatus.

Any condition which produces diminished control by the highest faculties over the activity of lower centres, is liable to lead to regression to the earlier mode of reaction.

9. All healthy men can be affected if the intensity of the rotatory stimulus is pushed up to a sufficiently high degree. This may occur either from the fact that the head is held in some unusual position, as for example when looking upwards during spinning, or the actual rotation may be mechanically increased in rapidity.

In some cases the reaction to such excessive stimulation takes the form of giddiness with or without nausea; in others it is associated with that withdrawal of consciousness known as 'fainting'. When a man is made giddy he is in a state of confusion with regard to his relations in space. In the preliminary stages of 'fainting' his horizon is restricted and the world around disappears. Both states, pushed to the limits of endurance, end in unconsciousness.

10. Complete adaptation to disturbances of equilibrium in the air is associated with automatic control of the afferent and efferent activities of lower levels of the central nervous system. A perfect pilot desires that his machine shall behave in a certain manner, and the evolution occurs, exactly as an instrument in the hands of a skilled musician emits the appropriate sounds as soon as he becomes conscious of some harmonious phrase.

11. This acquired facility can be disturbed by any condition which leads to diminished control. Just as a golfer can be 'put off his game' by some physiological or mental state, so the aviator may lose his capacity to fly in consequence of conditions that vary so widely as a gastro-intestinal attack or domestic anxiety. Exhaustion, insomnia, the distress of war flying, anxiety or fear, can all lead to defective afferent and efferent control. Efficient automatic response is no longer possible, and the pilot begins to fly badly and to make bad landings.

12. But this loss of control over the activity of lower levels may be manifested not only in bad management of the machine, but in some dangerous reaction such as 'giddiness' or 'fainting' in the air.

13. Should this abnormal reaction assume the form of giddiness and nausea, it will be found in most cases that the patient has suffered from some discomfort when he first went into the air. Inquiry will usually reveal that he was unable to swing, with pleasure as a child, and that he tended to be sick when travelling by train.

On the other hand, all the five pilots who came under my care for 'fainting', enjoyed their first flight and could swing with pleasure.

In the first group rotatory impulses, when released from control, manifested their influence in giddiness, usually accompanied by nausea. Amongst those who 'fainted' in the air the resistance to vertigenous impressions was high and no excessive giddiness resulted; but they induced the effects of shock with undue facility.

12.—MENTAL APTITUDE FOR AVIATION

BY

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In collaboration with the late Lieut. E. G. Maxfield, R.A.F.

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The chief object of our investigation was to discover whether it is possible to detect a mental aptitude for aviation by means of a conversation.

With this aim two of us (E. G. M. and W. H. R. R.), independently of one another, conversed with a number of pupils under instruction at Hendon, and endeavoured to form an estimate of their capacity for flying.

All those examined were put through the Domino Test by another of us (T. S. R.), who estimated the mental aptitude on the ground of this test and their general demeanour. The conversations took as a starting-point the answers to the following series of questions:

Name.
Age.
Previous service and regiment, if any.
Married or single.
Occupation in civil life.
What school did you go to?
How many boys were there?
In what form or class were you?
What games did you play?
Did you play for your school in any game or games?
What was your age on leaving?
Do you ride a horse, hunt, sail a yacht?
Do you motor?
What is your favourite amusement?
Who is your favourite author?
Who is your favourite poet?
Do you take alcohol?
Have you ever recited or made a speech in public?
Do you mind solitude?
What is your attitude to flying?

These questions were designed to give an outline of the pupil's history and some of his interests before joining the R.A.F. The information so obtained was taken into account in estimating the

aptitude for flying, but it was of less weight than the general impression made by the pupils, and information which would never have been given in the answers to a *questionnaire*. It is important to note that the conversations were private, thus getting rid of any constraint due to the presence of onlookers. We endeavoured not only to say whether in our opinion pupils would or would not succeed as airmen, but to grade them to different kinds of flying. We grouped them in four classes. In Class A we placed those whom we thought would make fighting scouts; in Class B those who would be successful in other kinds of flying; in Class C we placed those we expected to succeed in graduating, but who would not become good pilots, and Class D was for those we expected to be total failures.

For several reasons the investigation was unsatisfactory, and little weight can be laid on any results which have been obtained.

Our work forms little more than a preliminary study adopted to discover how an investigation of this kind should be carried out in future.

Some of the defects of the work are due to the unfortunate death of Lieut. Manuel in a flying accident. When this occurred we had only examined 37 pupils. Of these two had already been found to be unsuited for flying when they came to us for examination, and two others had had crashes, introducing a complication which made their exclusion necessary.

Our work is therefore based on the examination of the wholly insufficient number of 33 subjects.

A second defect of our work is that we had not at the outset made up our minds clearly concerning the nature of the aptitude we were studying. Our attention was directed chiefly to the capacity for flying, and we paid too little attention to endurance and capacity for fighting, which are quite as important as the capacity for flying in relation to the present needs of the Air Force, and, as already mentioned, our grading was based chiefly on our opinion whether the pupil would make a good scout pilot. These pupils formed our A Class, and we put in the second class men whose powers of endurance and capacity for fighting would make them quite as efficient members of the Air Force as many of those we put in the first class. Our attitude was changing even during the short investigation. If it had not been for Lieut. Manuel's death we should have certainly begun again with a more clearly formulated system of grading.

A third and very serious defect is that all the pupils had already had some experience of flying when they came to us. This greatly diminishes the value of our work as a guide to the use of conversations as the means of detecting aptitude in candidates for admission to the R.A.F. We tried to base our opinion on evidence independent of flying experience, but inquiries into the attitude towards flying are essential in any such work as we were attempting, and in these inquiries it was impossible not to be influenced by references to actual flying experience. These, indeed, would play a part even if we had rigorously excluded all reference to flying.

Finally, our work is incomplete, owing to our failure to obtain any record of the progress of many of the candidates, and even where we have received reports, these in many cases give too

little information to allow any satisfactory comparison with our estimates.

Reports have been received concerning 21 of the 37 pupils examined. Of these progress has been reported as 'very satisfactory' in four cases; 'satisfactory' in six; 'average' one. In two cases pupils have been found unsatisfactory as scouts, and had been recommended for heavier machines, and two other cases were reported 'unsatisfactory' without qualification. In three cases the report is that the pupil has done no flying and in one that he is ill. Three of the small number we examined have been killed: in two of these cases no information is given concerning progress before the fatal accident, but in the third case the pupil had made very satisfactory progress in Camels when he was killed, owing to a wing breaking off his machine. In the following table, which gives the estimates of the three examiners, this pupil is therefore entered under the heading 'very satisfactory'.

	E.G.M.	*W.H.R.R.*	*T.S.R.*	*Ipswich Test.*
Very satisfactory.				
C.B. 22	A	B	B	10–67
S.K.F. 21	A	B	B	10–67
A.B.R. 18	A?	A	A	10–57
P.G.W. 24 (killed)	A	B	B	9–63
Satisfactory.				
S.G.B. 23	B	B	B	11–62
R.E.N.	A	A	B	11–93
A.B.S. 19	A	B	B	10–72
W.R.W. 21	B	B	B	10–66
G.H.W. 19	B	A	B	11–61
W.C.G. 23	A	B	D	10–80
Average.				
L.B.J. 19	A	B	A	9–54
Unsatisfactory scouts. Recommended heavy seaters.				
F.T.C. 23	B	A	A	12–72
G.E.P. 21	B	B	A	8–54
Unsatisfactory.				
A.B.R. 19	B	B	A	10–68
W.G.W. 28	B	C	B	10–62
No flying.				
H.T.B. 27	—	B	B	10–72
J.C.B.	B	B	B	11–83
G.H.S.	A	A	B	11–84

Ill. 1.

	E.G.M.	*W.H.R.R.*	*T.S.R.*	*Domino Test.*
E.V.W. 19 . . .	B	B	A	9–49

Killed.

F.B. 22 . . .	B	B	B	10–58
J.C.D. 18 . . .	A	A	B	10–63

The most striking feature of these results is that Lieut. Manuel was very definitely more successful in estimating the aptitude for flying than either of his medical colleagues. Only in one case, that of L. B. J., was he definitely wrong.

The numbers are too few to allow any estimate of the value of the Domino Test, but the general impression given by the results is that taken alone it is of no great value. Of the two candidates who did it in the shortest time, the progress of one was unsatisfactory, and the other had only an average record. Of the four candidates who were found 'very satisfactory' only one did the Domino Test in less than 60 seconds.

A much larger number of examinations, however, should be made before any decision concerning this value of the test should be reached.

Though our work is based on too small a number of examinations and has many defects of method, it has been useful in pointing to the methods upon which such an investigation should be carried out in future. We therefore make the following suggestions:

(*a*) An investigation designed to discover whether it is possible to detect mental aptitude for the work of the R.A.F. should be carried out on pupils before their admission to a flying school, and most appropriately at the school to which they go immediately after admission to the Force.

(*b*) It is not enough to grade simply into classes according to general aptitude, but it is necessary to distinguish between such features as manipulative ability, fighting capacity, endurance, and intelligence.

The following scheme illustrates the nature of the grading which is now being used at the 29th Training Squadron:

Ability.	*A.*	*B.*	*C.*	*Remarks.*
Manipulation .				
Fighting . .				
Endurance . .				
Intelligence . .				

(*c*) Our work suggests that pilots who have the necessary interest in the subject will form the most suitable persons to act as examiners.

(*d*) The fatiguing nature of such examinations makes it quite impossible that they can form part of the general tests

for admission to the R.A.F. The existence of mental aptitude for flying is probably most important in borderline cases, among whom the presence of definite aptitude might be allowed to counterbalance a degree of anatomical or physiological defect which would otherwise lead to rejection. For this purpose special examiners might interview selected cases, or this inquiry might form part of the work of the assessors. In general, however, inquiries into mental aptitude would come most appropriately at an early stage in training, and should be used as one of the means of excluding unsuitable candidates who have succeeded in obtaining admission to the R.A.F. on the ground of physical and physiological suitability.

APPENDIX ON 'WIND-UP'

BY

W. H. R. Rivers, M.D., F.R.S.

The expression 'wind-up' was probably used originally for any state of mingled excitement and apprehension called into being by an unusual occurrence, and especially the prospect or actual presence of danger. It has, however, gradually come to be used in the army as a means of expressing fear in one or other of its forms, an expression by means of which a soldier will talk about fear without explicitly acknowledging the presence of this emotion. I propose here to use the word as a definite expression for fear.

Fear is the emotional or affective aspect of the instinctive process called into activity by danger. It is the modification of consciousness which accompanies certain instinctive forms of action in response to danger, and especially the response by flight. It is especially intense when there is interference with this or any other form of reaction to danger.

It is only in Man that we are able to study by means of introspection the various forms of fear. The first distinction to be made is between the emotional state or states accompanying the actual presence of danger and the various forms of fear which arise when there is only the prospect of danger, while in pathological states a large group of fears or states allied to fear occur independent of either actual or prospective danger.

Reaction to actual danger. The most frequent reaction to danger in Man is one of heightened capacity for the activities by which the danger may be met without any trace of the fear which, if present, would inevitably interfere with this capacity. A man in the presence of danger will carry out with the utmost coolness, and often with a degree of skill surpassing that he usually shows, the measures necessary for the aversion of the danger or his escape from it. In such a case there is complete suppression of the emotion of fear which the danger might be expected to produce, and this suppression is nearly always accompanied by suppression of pain, so that an injury derived from the dangerous object or from any other source is not perceived.

A second mode of reaction is the assumption of an aggressive attitude towards the source of danger with the accompaniment of the affective state of anger. In this case there is not a simple suppression of fear, but its place is taken by another emotion belonging to the instinct of aggression. If these lines of action fail, if the serviceable activity which would lead to escape from the danger is interfered with or becomes impossible to carry out, or if the aggressive reaction does not succeed, fear supervenes as an accompaniment either of flight or of the collapse which is apt to occur when the more normal and serviceable reactions fail. In some cases, however, the suppression of fear is so well established that this emotion remains completely absent even when the danger is so insistent and unavoidable that death or violent injury is inevitable. Thus, the emotion

of fear may be completely absent during the fall and crash of an aeroplane in which death seems certain its place being taken by an interest such as might be taken by the mere witness of a spectacle, or by some apparently trivial line of thought. It is when some line of action is still possible, but this action is recognized to be fruitless and in vain, that fear, often in the acute form we call terror, is likely to supervene.

Reactions to prospective danger. The state most commonly produced by prospective danger is one of that degree of fear which we call apprehension. This may be so intense as to become indistinguishable from the fear which accompanies the active presence of danger, but it is more usually a vague discomfort, with minor degrees of the tremor and muscular weakness which accompany fear.

This state of apprehension may occur, often in a relatively intense form, n men who become perfectly cool and collected as soon as the danger becomes actual, when the state of apprehension completely disappears so that there is no interference with the activity by which the danger may be averted. The apprehension preceding the occurrence of danger is of exactly the same order as stage-fright or the fright preceding any other public performance, and just as the best actors and orators are liable to stage-fright, so may those who show the utmost coolness and bravery in the actual presence of danger be liable to apprehensions while the danger is still only in prospect.

In other cases the apprehensions at the prospect of danger are so acute and so accompanied by physical manifestations which make appropriate action impossible that the actual occurrence of danger only serves to bring about complete collapse.

Pathological fears. Fear is a very frequent accompaniment of pathological states, and many of its more extreme forms only occur in adult Man as part of such states.

The most frequent form in which such intense fears arise is the nightmare or the night-terror of the half-waking state. These are especially characteristic of childhood, but they may occur in adult life in those who seem otherwise healthy, while they have recently become familiar as the most prominent symptom of states of anxiety arising out of the war.

Similar intense fears may occur in the first stage or following the administration of an anaesthetic, or attacks of terror may occur in the waking state as part of an anxiety-neurosis.

Another pathological form taken by fear is shown by the various phobias, in each of which some special stimulus may arouse fear in one who otherwise may not know what fear means. The stimulus which thus arouses fear, often in a very intense form, may be one which in other persons not only wholly fails to arouse this emotion, but may be a source of definite pleasure. Thus, a man who does not know fear in the presence of actual danger to life or limb, may suffer from acute fear in the presence of a cat or a harmless snake, or an airman who is only stimulated by the utmost danger of aerial warfare may suffer from acute apprehension in a lift or on a ladder only a few feet from the ground. These highly specialized fears also occur in relation to definite sources of danger; thus, one who is undisturbed by most of the dangerous situations of warfare may have some special fear, whether of searchlights, sniping, or some special kind of shell.

Still another form of fear is the more or less persistent state of anxiety which forms so prominent a feature of the functional nervous disorders arising out of warfare that it has been adopted in the nomenclature of one of the most frequent forms taken by these disorders. In the healthy person anxiety is a state which comes into existence in consequence of some prospective misfortune or danger, but in morbid conditions it shows itself in the form of more or less continuous apprehension colouring the whole mental life, so that even the most ordinary occurrences are seen in the blackest light as sources of trouble or danger.

Suppression and repression in relation to fear. In the form of reaction to danger which seems to be characteristic of the normal healthy man, there is a complete absence of the emotion of fear. No effort is needed to keep fear out of the mind, for it shows no tendency to appear in consciousness, and yet fear in the presence of danger is so necessary a part of the mental equipment of animals and is so frequently manifested in childhood that we can confidently assume

this emotion to be potential, present but not [illegible] of expression. The assumption is supported by several lines of evidence. A man who is exposed to danger experiences no sense of fear and remains quite [illegible] and bravery may yet suffer [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] as there is much reason to believe, suppressed affective states find expression in dreams owing to the weakening of the [illegible] control in the sleeping state, the occurrence of fear in dreams following a distressing experience would be a natural consequence of its ordinary existence in a state of suppression.

Still more important and conclusive is the occurrence of fear as the result of shock or long-continued strain and fatigue which lower the efficiency of the higher controlling levels of mental activity. Thus, one of the earliest signs of the strain of warfare is the occurrence of apprehensions in one who till then has passed through the dangers of warfare without fear. The occurrence of fear either manifestly or in the form of vague apprehensions when shock or strain has lowered efficiency is naturally explained if the fear has been there throughout, but in so complete a state of suppression that it never passed the threshold of consciousness. As soon as fear or apprehension begin to show themselves in consciousness, a new process comes into action. The fear, no longer held unconsciously in check, has now to be consciously repressed. One who has flown or fought, perhaps for many months, without knowing fear, finds himself the subject of apprehensions which he regards with shame and strives to banish from his mind. A short rest at such a time, by allowing the unconscious controlling process again to take the upper hand, will often bring about the disappearance of the apprehensions, so that danger can again be faced with impunity and without the necessity for conscious repression. Or the lowered efficiency of the controlling forces may be temporary and the recuperative power of the sufferer may be so great that recovery of the normal state of suppression may come about, so that conscious repression again becomes unnecessary. More frequently, however, the conscious repression of fears or apprehensions only adds to the strain and fatigue which has led to the failure of suppression. The fears become stronger and call for still stronger efforts of repression. Through the vicious circle thus set up there is produced a state of persistent anxiety in which even ordinary incidents of life, incidents wholly devoid of danger, come to be viewed with apprehension. The fears which are repressed with apparent success during the day find expression in an accentuated form at night, when the control exerted by day is removed in sleep or weakened in the state preceding or following sleep. The interference with rest so produced only serves to increase the state of strain and fatigue to which the nightmares or disturbing night-thoughts are primarily due, while disturbances of digestion or circulation due to the anxiety may react on and accentuate the state to which they are primarily due. Finally, some shock or additional strain, a slight accident which a few months before would only have raised a laugh, a misunderstanding with a superior officer or some domestic trouble, will bring about a crisis and reduce the soldier to a state in which he becomes wholly unfit for any kind of duty. The morbid state which most frequently supervenes is that known as anxiety-neurosis, which is only an exaggeration of the morbid state of anxiety which preceded his definite breakdown. In other cases, the trouble may find expression in some mimetic disability usually known as hysteria, while in those of psychopathic disposition, there may be complete mental collapse, or the unbearable situation may be solved by the occurrence of those false rationalizations which we call delusions.

The special feature of practical importance in the foregoing statement of the various forms taken by the emotion of fear is that the occurrence of this emotion may be a symptom, often the earliest symptom, of a state of fatigue and strain Owing to the way in which the society to which we belong, and especially those whose business it is to fight, look upon fear, its occurrence, especially without adequate cause, arouses other emotions, and especially that of shame, which greatly enhance the strain to which the fear is primarily due.

Treatment. It is evident that the state so produced is one which gives ample scope for treatment, both preventive and curative. There is no department of medicine in which a medical officer can gain results so definite as in the treatment of the early stages of the anxiety-neurosis of warfare. The earlier he can act the better, for the longer the state of anxiety is allowed to last, the greater

the conscious repression which becomes necessary, the longer is the period of rest which is required to enable the process of suppression to become again effective. Moreover, the occurrence of disturbances of circulation, of digestion and of other organic functions may produce complications which greatly prolong the process of recovery. Nowhere is the adage more appropriate that a stitch in time saves nine.

A medical officer can only hope to succeed if he is on such terms with those under his care that they are ready to give him their full confidence, for owing to the general sentiment regarding fear, it is only with the greatest reluctance that its presence is acknowledged. It is here that the expression 'wind-up' has its peculiar utility in that it enables one in whom strain is producing apprehensions to refer, half seriously, half humorously, to his trouble. The first step in the treatment is to assure the patient that there is no cause for shame, that the fear he experiences is a well-recognized symptom of strain and is due to the temporary failure of the mechanism by which in the healthy and normal man fear is kept under adequate control. If sleep is already disturbed by dreams, a second line of treatment will be to induce the sufferer to give up the process of voluntary repression to which, in the vast majority of cases, these dreams are due. Having by this process of education put the patient on the road to recovery, a short rest followed perhaps by a period of limited duty, will usually restore him to his normal level of efficiency. To send him for a holiday without the necessary process of education and reassurance is open to the serious risk that he will only continue during the holiday to repress or brood over his painful thoughts and feelings, with the result that the state of anxiety is accentuated and becomes a fixed habit.

Finally, it must be pointed out that this line of treatment only holds good for those in whom the occurrence of fear is clearly the result of shock or strain. Those who are naturally apprehensive require a different line of treatment. Their case is far more difficult and less hopeful than that in which fear is secondary to strain or shock, but much can be done with them by sympathetic encouragement in fighting their disability, and when possible, by gradually introducing them to the conditions which rouse their apprehensions. There is reason to believe that in some cases such apprehensions are the definite sequel to some emotional shock in childhood or youth which has set up faulty trends in feeling and behaviour. In such cases, a thorough and sympathetic discussion of the history of their fears may be of great service and may at least allow the medical officer to recognize how far the state is capable of amendment, whether there is a reasonable hope that the patient may acquire that state of suppression of fear

13.—'REACTION TIME' TESTS CARRIED OUT ON FLIGHT CADETS, WITH DESCRIPTION OF APPARATUS

BY

The Late L. E. Stamm, M.D. late Lieutenant R.A.F.

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For the past year or so the value of employing 'reaction time' tests in the selection of candidates for aviation in the Air Service has been under consideration. In France a scheme of simple reaction time tests has been adopted, by which a normal neuro-muscular response to the different senses is ensured. In America the simple reaction time tests have been rejected as too automatic and of no value for the purpose in hand, and more complex tests have been adopted, in which conscious mental processes of discrimination are involved.

On *a priori* grounds it appeared to me that simple reaction time tests could be of little practical value for the Air Service, because in healthy young men with normal senses and muscles, the co-ordination between these and therefore the 'reaction time' is sufficiently quick and accurate for all practical purposes, and in actual experience I have obtained some comparatively slow reactions from very capable individuals and very quick responses from some of poor mentality. In candidates for the Air Service I do not think these simple reaction time tests would eliminate 1 per cent. of undesirables.

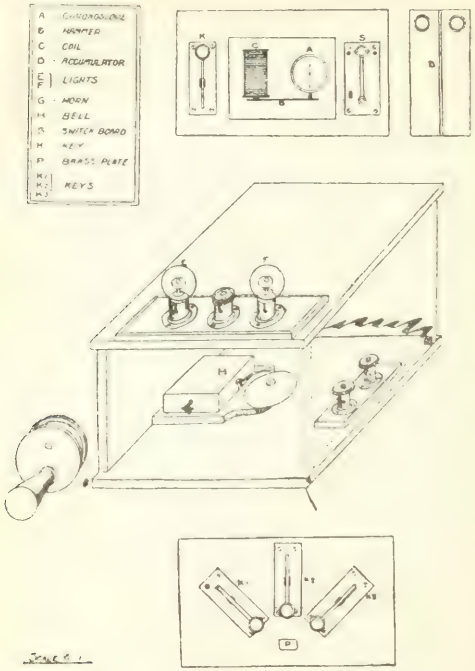
What one requires to test is the ability of the candidate to respond quickly and accurately under conditions in which the higher *conscious* mental functions of discrimination, decision, and judgement are involved. For this purpose one has a number of different signals, requiring different responses, the candidate not knowing which signal to expect. This necessitates the intervention of the conscious mind between the perception of the signal and the motor response, and consequently the reaction time is lengthened. The mental ability is tested by the rapidity and accuracy of response in proportion to the complexity of the problem presented to the candidate.

Many forms of apparatus have been devised, but as the interval of time is only a fraction of a second, and variations are measured in 1/100ths of a second, some difficulty has been found in obtaining accurate and reliable apparatus that is also sufficiently simple for practical purposes.

With the help of Major Burgess, engineer, R.A.F., I have devised an apparatus which is comparatively simple, and which in practice has proved of value in testing candidates for the Air Service. A diagram of the apparatus is shown below.

Reaction Time Apparatus

It consists of a chronoscope *A*, which registers to 1/100 second, and is worked electrically by a hammer *B*, from a coil *C*, and accumulators *D*. There are four signals, two differently coloured lights *E* and *F*, an electric horn *G*, and an electric bell *H*. The operator has a switchboard *S*, by which any of the signals is put in the current,



and the signal is given by touching the key *K*. The candidate sits opposite the operator and places his right-hand first finger on the brass plate *P*, which is equidistant from the three keys K_1, K_2, K_3. The end keys, K_1 and K_3, are for the corresponding lights, and the middle key, K_2, is for the horn or the bell. It was not considered desirable to complicate things to the extent of four keys.

When the operator presses his key *K* one of the signals is given, and at the same time the chronoscope starts. The candidate responds by touching the appropriate key, K_1, K_2, or K_3, which stops the chronoscope, and the reaction time is read off in 1/100th seconds.

The method of examination is as follows: After a short pre-

liminary rehearsal to acquaint the candidate with the method of working the apparatus, the candidate is tested for the simple 'automatic reaction time' by one signal, which he knows to forehand. He is tested in this way by a series of each of the four signals. As already stated, I set no value on these tests, but they enable the candidate to get used to the apparatus. After testing for the simple reaction time with each separate signal the candidate is now told that he may get either one of the two lights, and he is to respond by touching the appropriate keys K_1 or K_2. Having done a series of ten with the two light signals, he is now given a series with three possible signals, the two lights and the horn, and finally a series of all four signals—two lights, horn, and bell—but for the bell for which he has previously used the middle key, K_3, he is now told to keep his finger on the brass plate. This involves mental inhibition. Each series shows an increase in the reaction time, owing to the increased complexity of the problem before the candidate. Recently I have used a further series of four signals, in which the keys previously used for the lights, each corresponding to the light on the same side, are now reversed. This further complicates the problem and causes a further increase in the reaction time.

The following are the averages of 150 cases, including pupils and instructors (good pilots), for the different tests in 1/100th seconds :

(1)	Reaction time to single light signal	28
(2)	.. .. ,, sound	26
(3)	.. .. two lights	35
(4)	,, ,, ,, ,, and horn	38
(5)	,, ,, ,, ,, ,, two sound signals	44
(6)	,, ,, four signals with keys to lights crossed	48

Examination of 20 instructors (experienced pilots) in the same way yields, as would be expected, appreciably lower figures as averages for the 20 cases :

Simple visual reaction (one signal)	27
,, auditory ,, ,, ...	25
Two signal test (two lights)	32·4
Three .. .. (two lights and horn	34·5
Four ,, ,, (two lights and two sound signals)	40·4
.. ,, ,, (with keys and lights crossed) ..	46

Taking the last two tests as the crucial tests of the mentality of the pupil, I have found a remarkable correspondence between the results and their capacities as flying pupils. Having tested a certain batch of pupils, I send the names to their instructors, and ask for their opinion as to their flying capacities and possibilities of making good pilots. Arranging them in the order of the results from the machine, as a general rule the top names have 'very good' or 'good' against them, the middle ones 'fair' or 'average', and the bottom ones 'poor' and probably 'turned down' or sent to 'heavier machines'.

Appended is a list of pupils examined, with the results of the test

and the criticisms of their instructors, from which the value of the test can in some measure be estimated.

I should point out that with my apparatus there is a muscular adjustment involved in the movement of the finger to the different keys. In my opinion this is a valuable factor as a further test of the nerve mechanism, but it necessarily prolongs the reaction time, so that even the simple reaction time with my apparatus is longer than the usual without such muscular adjustment. It is quite easy to dispense with this for simple reaction to one signal by placing the finger ready on the key.

The value of the tests lies in the fact that they involve considerable adjustment and co-ordination between the senses and the muscles, and at the same time call for a rapid and accurate working of the higher mental functions of conscious discrimination and decision, a complexity of conditions similar to that involved in piloting an aeroplane.

Moreover, it calls for a prolonged effort of attention, and the ability to sustain the effort is shown by the way in which a candidate succeeds in keeping up his rate of response to the end of the tests, or shows evidence of mental fatigue by sudden lengthening of the time intervals or by mistakes in the keys.

Over and above everything else there is the 'will' factor to be taken into account. This may act in at least two different ways. It may be negative. Then the results of the tests will not represent the best that the candidate can do. Or it may be very positive. It may be exercised to such an extent that the candidate exceeds for a time his normal power of reaction. In this case the excess of his efforts usually shows itself by mental fatigue setting in before the tests are finished, and he is unable to keep up the pace he has set for himself. All these variations are very useful to observe in forming an estimate of the candidate's mental constitution and capacity.

I would, in fact, claim for the apparatus that it not only gives figures of some value for estimating the mental capacity of a candidate for aviation, but that it affords a means of employing a candidate in a way which gives considerable opportunity of making mental notes in regard to his intelligence and personality, by the manner in which he tackles the machine. Some tumble to the game at once and show a remarkably quick adaptability, whereas others are equally slow in picking up the idea, but may warm up as one proceeds and give quite a good account of themselves in the final tests. Some are light in touch and accurate; others heavy and clumsy, so that they often miss the keys and almost break them when they touch them. I have myself been surprised in dealing with pilots personally known to me to observe how the machine seems to bring out and record their personality, and especially their flying personality. There appear to be two good but different types of mentality which react differently to the apparatus. In the one the reaction times are very quick, but in cutting down the time allowed for discrimination to the utmost in the final tests several mistakes may be made. In the other good type the reaction times are appreciably longer, perhaps even above the average, but the signals are responded to with

absolute accuracy. The flashy, exact, neat pilot [illegible] type of reaction, while the steady, careful pilot is characterized by the second type of reaction.

In addition to these mental qualities of quick discrimination and decision, for which I have attempted to test by this apparatus, there is also the factor of 'emotional stability', to which I have also given some attention. It will be found on comparing the results of my apparatus with the opinions of the instructors that this factor of 'emotional stability' is the chief disturbing element in the co-ordination of the two columns. Pupils giving good reaction time results may be marked 'poor' by the instructors because they are 'windy', and others showing long reaction times may be marked 'good' because they have 'guts'. Very often I have notes to the same effect.

I have found that the pulse-rate under ordinary medical examination is a very fair guide to detect the 'windy' type. People who manifest their uneasiness at coming before a doctor for examination by a rapid pulse, which does not settle down in spite of every effort to put them at their ease, prove by that fact that there is a lack of control of the nerve mechanism of the vital centres, that there is an instability and liability to serious disturbances by the emotion of fear, and they belong to the 'windy' type. This instability does not appear to be in the vital centres themselves, but in the higher nerve centres controlling them, because such individuals respond to the ordinary physical test in a normal manner. The manometer test, the exercise test, show a perfectly normal acting mechanism: it is the rapid pulse of emotional disturbance.

It appears to me that a combination of reaction time tests such as I have carried out, with some tests for emotional stability, such as the pulse-rate test and perhaps the galvanometer test, should offer very satisfactory results in the selection of candidates for aviation, in regard to their mental and temperamental suitability for the work.

FLIGHT GROUP No. I.

Name.	4-signal test in 1/100 sec.	Remarks of M.O.	Instructors' Remarks.
I.	31	Haphazard, W.7.	Good, lacks judgement.
II.	35	Very intelligent and quick.	Very good now instructor.
III.	35·5	P. 120. Nervy but guts mentally.	Fair—nervy, drinks too much
IV.	36	Sturdy, sports, W.3.	Good but slow.
V.	38	Sturdy Canadian, horse-riding.	Good, quick, guts.
VI.	39·5	—	Average.
VII.	39·5	All there—guts.	Good—plenty of guts.
VIII.	39·5	Says upset by 3 instructors.	Poor, no guts, gets sick.
IX.	40	No nerve physique.	Average.
X.	41		Very good: steady.
XI.	42	—	Good.
XII.	42	Capable, good type.	Extra good.
XIII.	42	—	Average.
XIV.	42	Alert, good type.	Very good—now instructor.
XV.	42	—	Average, just started flying.
XVI.	43	Intelligent.	Good.
XVII.	43·5	Sports, average intelligence.	Fair—guts.
XVIII.	44	—	Average.
XIX.	44·5	Uptake slow.	Good but silly.

Name.	Perceptual test 1/100 sec.	Remarks of M.O.	Instructor's Remarks.
XX.	44·5	Lethargic.	Slow but solid.
XXI.	46	Dumpy.	Average, slow.
XXII.	46	Musical, nervy.	Fair.
XXIII.	46	Slow uptake, no sports, clerk.	Average.
XXIV.	47	Slow uptake, no sports, clerk.	Average, slow learning.
XXV.	47	Alert—sports.	Good.
XXVI.	47	Nervy.	Poor—windy.
XXVII.	47·5	Very anxious, W.4.	Average, persevering.
XXVIII.	48		Poor—sent to heavier machines.
XXIX.	49	Windy, paralysed by horn signal, bad type.	Poor—windy.
XXX.	50		Average, large flying experience.
XXXI.	50·5	Bank clerk, not robust.	Average.
XXXII.	50·5	Bright; guts.	Good—lots of guts.
XXXIII.	50·5		Poor. ? Windy. To be turned down.
XXXIV.	52	Slow but good type.	Slow, but will make good.
XXXV.	52		Fair.
XXXVI.	52	Sturdy—rough and ready.	Fair—solid—heavy-handed.
XXXVII.	52·5	Slow and dull.	Average to poor.
XXXVIII.	53	Nervy, sick on stunting.	Poor.
XXXIX.	55	Heavy—dull.	Poor—sent to heavier machines.
XL.	55·5	Dull and windy.	Poor—sent to heavier machines.
XLI.	57		Poor.
XLII.	75·5	Mentality very poor.	Hopeless.

FLIGHT GROUP No. II.

XLIII.	33	Journalist, M.A. Alert, no sport.	Good, but previous experience.
XLIV.	36·5	Average.	Good.
XLV.	37	Good type.	Very good.
XLVI.	37·5		Good—guts—keen.
XLVII.	39	Good type. Canadian.	Very good.
XLVIII.	40	Good type.	Good.
XLIX.	40	Average.	Good.
L.	40	Quick but bumptious and over-confident.	Good but objectionable.
LI.	40·5		Average.
LII.	40·5	Heavy Scotch type—guts.	Average, perseveres.
LIII.	41	Good type.	Very good—now instructor.
LIV.	41		Good.
LV.	41·5	Average.	Good, slow learning.
LVI.	41·5	Bright and intelligent; guts.	Very good and keen.
LVII.	41·5	Accountant, lethargic and heavy.	Heavy-handed; to be turned down.
LVIII.	41·5	Lack of muscular adjustment.	Poor and slow.
LIX.	42	Good type—sport.	Very good, steady and keen.
LX.	43	? Windy.	Good but windy.
LXI.	43		Average, rather slow.
LXII.	43	M.C.	Good but slow learning.
LXIII.	43·5	Heavy.	Good but slow learning.
LXIV.	44		Keen but lacks judgement, windy.
LXV.	44·5	Nervous temperament but not windy.	Average, keen, guts.
LXVI.	44·5	Sports, horse-riding.	Average, keen, guts.
LXVII.	45·5		Average but slow.

W. = mistakes in keys
M. = mentality. A. good. B. average. C. poor.
Where not stated mentality is average.

Name.	Age.	Remark of M.O.	[illegible]
LXVIII.	46	Good type.	Good.
LXIX.	46.5	Good type Canadian.	Good.
LXX.	47	Average.	Good and very keen.
LXXI.	47		Average to poor.
LXXII.	48	Little stamina, clerk.	Average.
LXXIII.	48	Average—no sports.	Average.
LXXIV.	48	M.C. slow.	Good guts—slow learning.
LXXV.	52.5	P. 96. Tremors, ? windy.	Average—windy.
LXXVI.	49.5	Average.	Slow—improving.
LXXVII.	50.5	Nervy.	Poor—windy.
LXXVIII.	51	Sports.	Poor but guts.
LXXIX.	53	M.C. not good type.	Very slow, to be sent to heavier machines.
LXXX.	53.5		Average.
LXXXI.	54.4	M.C. heavy. W.5.	Hopeless, turned down.
LXXXII.	54.5	M.C. heavy.	Poor—very slow.
LXXXIII.	54.5	M.A. Bright. W.4.	Average.
LXXXIV.	56	Slow and dull.	Very poor—turned down.
LXXXV.	57	Windy—bad type.	Poor—heavy-handed.
LXXXVI.	58	Heavy—sports.	Average—guts.
LXXXVII.	58	M.C. but guts, drinks too much.	Average—guts.
LXXXVIII.	61		Poor.
LXXXIX.	66	Civil Service clerk.	Poor—slow.

FLIGHT GROUP No. III.

XC.	34	Alert—bright.	Very good.
XCI.	35	Average.	Average, not keen.
XCII.	38	Canadian, good type, sports.	Very good.
XCIII.	38	Good type.	Very good.
XCIV.	38	—	Average.
XCV.	39	M.A. Good type.	Very good—now instructor.
XCVI.	40	M.A. Rather slow in uptake.	Very good.
XCVII.	40	—	Poor—inattention.
XCVIII.	40	M.A. Alert.	Good.
XCIX.	42	Good type—sports.	Very good.
C.	42	Windy.	Intelligent but no guts.
CI.	42	Artistic. M.A.	Good.
CII.	43	—	Good.
CIII.	43	—	Good.
CIV.	43	—	Good.
CV.	43	—	Fair, lacks confidence.
CVI.	45	Good type—bright.	Good.
CVII.	45	No physique—windy.	Poor, windy and sick.
CVIII.	45	-	Average to good.
CIX.	45	Alert and bright, good physique.	Average to good.
CX.	46	Rough type.	Average to good.
CXI.	46	—	Good.
CXII.	46	Canadian, rather stolid—guts.	Good.
CXIII.	47	Canadian, sports, M.A.	Good but very slow.
CXIV.	47	Stolid but guts.	Good—guts.
CXV.	47	Russian, intelligent.	Average.
CXVI.	48	—	Average.
CXVII.	48	—	Average.
CXVIII.	48	Alert—guts.	Average.
CXIX.	50	M.B. Slow in uptake.	Average.
CXX.	50	—	Average.
CXXI.	50	Slow—stolid.	Good, guts.
CXXII.	50	-	Poor.
CXXIII.	52	Too talkative and plausible, windy.	Average—windy.

W. = mistakes in keys.
M. = mentality. A. good. B. average. C. poor.
Where not stated mentality is average.

Name.	4-signal test in 1/100 sec.	Remarks of M.O.	Instructor's Remarks.
CXXIV.	52	Bright and intelligent.	Average.
CXXV.	52	—	Average.
CXXVI.	52	–	Average.
CXXVII.	52	Good type Canadian, sports.	Average.
CXXVIII.	53		Average.
CXXIX.	54	–	Poor.
CXXX.	54	M.C.	Average to poor.
CXXXI.	54	M.C. heavy.	Poor.
CXXXII.	55	—	Poor.
CXXXIII.	56	Haphazard, M.C.	Average.
CXXXIV.	56	Rather heavy but good type.	Average slow but solid.
CXXXV.	56	Feeble mentally and physically.	Average to poor.
CXXXVI.	63	Poor type.	Average to poor.
CXXXVII.	63	-	Average.
CXXXVIII.	66	Slow but sturdy, horse-riding.	Average to poor, very slow.
CXXXIX.	68	Charterhouse School, but slow, heavy.	Poor—very slow.

W. = mistakes in keys.
M. = mentality. A. good, B. average, C. poor.
Where not stated mentality is average.

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